# A STUDY OF FACTORS AFFECTING EARLY SPRING GROWTH OF GRASSLAND

Robert H. L. JACK, M.A., B.Sc.(Hons.)

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## INTRODUCTION

Many people have said that grass is the major crop of British agriculture and this assertion has been heard with increasing frequency in recent years as the truth behind it has been more widely realised. In point of sheer acreage, more land in the United Kingdom is growing grass than any other crop but very little of that land is growing the maximum quantity of grass or even grass of top quality. Under these conditions, in a country such as ours where soil and climate are so favourable to grassland production, there is obviously great scope for improved management and utilisation.

There have been great advances in this realm of agriculture in recent times. Grass strains have been improved by breeding, the employment of rotational grazing, new fertiliser techniques and conservation by ensilage are only a few of the means which science has developed to the benefit of grassland practice. The ready acceptance of new techniques has largely sprung from the exigencies of our current high cost economy. The emphasis on improved grassland husbandry has increased enormously as stock-farmers have endeavoured to make more use of their grass crop. This is a highly nutritious and relatively cheap food for grazing stock. Hence it is worth exploiting as a crop and is not mrerely to be taken for granted as if it were outwith the rules of good husbandry.

Until very recently this exploitation has concerned the grazing season from May to October. The improvements in farm practice regarding summer grass have been considerable since the war. Now the exploitation is extending to the other "out-of-season" period and ways and means are being sought to grow and utilise fresh grass at this period. Before the final test of whether it is worth growing grass earlier and later in the season can be decided the practicability of so doing must be investigated. That task is the object of this work.

It is well to realise that "in-season" and "out-of-season" are not so abrupt that the "in-season" period cannot be extended a little at a time at the expense of the "out-of-season" period. It is also worth considering that the cost of production of grass in the normal growing season is so low that even if it costs more to produce in the adverse period of the year its value is even greater at that time. In the late autumn other cheap forage crops like kale are available as substitutes for grass but in the early spring no such fresh substitute exists.

It therefore seems worth while to study the factors affecting grassland growth in early spring with a view to shortening the effective winter period and so reduce the farmer's dependency on conserved foods and concentrates. To gain a benefit of even one week in earliness would be valuable when the cost of concentrates for a herd of dairy cows or a flock of ewes and lambs at this period is considered. By thinking along these lines it became obvious that much more knowledge was required of this topic from work done here in south east Scotland. In this way the work began.

Since the conception of this study took place and more particularly since the actual trials were laid down in May 1956 there have been many difficulties. Mishaps, adverse weather, physical limitations on size and scope of the research projects but in some ways the most difficult of all has been the popular interest in work on this topic. The catch-phrase "early-bite" has become commonplace and almost every seedsman's catalogue and every vendor of fertilisers purports to have the answers to the problems of producing early spring grass. That some measure of advantage can be derived from these two means, the correct seeds and fertilisers, is true but it is obvious that far more basic knowledge must be gained than is possessed by the glib salesmen. The facts they use are often scanty, unsound scientifically and gained at second or third hand. That they do not have all the answers to all the problems is confessed by themselves privately and also by the avid interest of practical farmers for more information from those engaged in the systematic study of this topic.

It is certain that much attention is being given by large commercial and government research institutions to this sort of work. It is hoped that the contribution given in this volume will aid these endeavours and provide some small benefit to British agriculture.

## LITERATURE

A review of knowledge already established relative to this study.

The aim of this project was to study the major factors influencing the earliness of spring growth in grassland. It is certain that only by a fuller and more accurate knowledge of how these factors act and interact on grassland can any real advance be made in producing herbage early in spring. The factor having the greatest single effect upon spring growth is weather and not only is this unpredictable but it cannot be manipulated to our requirements. Nevertheless by employing the means at our disposal to vary the other major factors it seems possible to modify adverse weather to some degree. The aim of producing earlier grass is clearly a comparative endeavour - an attempt to produce grass before it would otherwise be available. The aim cannot be an absolute one of obtaining a given amount of grass per acre by a certain date in the present state of our knowledge because climate is the key to this. Only by aiming at a comparative advantage can the full difficulties of climate be side-stepped and the results of manipulating the other major factors become the key to success.

The existing knowledge on these other factors embraces the suitability of different species and strains of grass and clover for early spring production, details of cultural techniques advantageous to early growth and certain relevant information on plant physiology. There is in existence much useful information concerning soil conditions and the use of fertilisers, especially nitrogenous fertilisers, the nutritional value of the grass product and other matters all of which is highly relevant to this topic of early grass production. This existing knowledge is subjected to a critical appraisal in the review of literature which occupies the first section of this work. The second section concerns the field trials which have been conducted on the basis of the existing knowledge. These have varied in size and complexity depending on their aim and the material employed. In a few instances these have set out to test the validity of results already obtained elsewhere, for the conditions ruling in south-east Scotland. In the others the aim has been to obtain new information and to test new ideas and techniques. All of which could be summed up as directed towards increasing existing knowledge on early grass production.

## I. HISTORICAL

Any scrutiny of grassland literature will reveal that very little is dated prior to the Twentieth Century. Virgil and Columella wrote of flocks, pastures and farming methods in Roman times. A few farming works survive from the medieval period and the Eighteenth Century brought a number of publications from people like Arthur Young. In the mid-Nineteenth Century there were no authoritative works on grassland matters. Farming was concentrated upon arable cropping and before 1880 only botanical classifications of grasses existed and virtually nothing was known about the agronomic value of different grasses. In the Nineteenth Century a trade in grass and clover seeds, chiefly in ryegrasses and red clovers, was operating. Lawson, an Edinburgh seed merchant, published a treatise on grassland in the middle of the Nineteenth Century which was reasonably accurate and served as a reference on the subject for many years.

It was not until the depression in arable farming began in the 1880's that interest in pasture land developed. Stock husbandry was still remunerative and it required good grassland. Names like Faunce de Laune and Elliot of Clifton Park came to the fore as a result of their investigations into pasture improvement. The most productive pastures in those times were the fattening pastures of the South Midlands. It was these permanent pastures which were studied and copied. The Agricultural Societies of both England and Scotland were commissioning botanists to analyse the constituents of such pastures. Seed mixtures were then designed to contain the species so found in the hope that similar pastures might thus be created. This led to the incorporation of long lists of grasses and herbs in mixtures which read more like recipes than seeds prescriptions. The importance of management as a factor influencing a pastures composition and quality was not generally realised. The effect of the grazing animal on pasture plants was not understood for a long time, in fact until A.G. Tansley developed the study of ecology.

To us now these early endeavours appear like blind gropings after knowledge. Many esteemed fattening pastures contained weeds and weed-grasses which were incorporated in the seed mixtures fashioned after them. There was no way of telling good constituents from poor ones for there was then no way of evaluating them. In the early years of the present Century Somerville at Cockle Park actually measured the produce from a pasture by weighing the grazing sheep and so obtaining the live weight increase grained from a period of grazing. This marked the beginning of a scientific approach and the first development of methods of assessing results.

We now have the aid of statistical methods for such evaluation and are able to determine with reasonable certainty the validity of any results obtained and to interpret their meaning. Replicates and randomised plots were not used in the Nineteenth Century. This does not mean that no accurate experimental work was done. The valuable findings on soil chemistry and arable cropping obtained at Rothamstead were entirely accurate. Accuracy was then achieved by averaging the results obtained over long periods of years rather than by employing mathematical criteria. Such methods are slow, very laborious and best suited to isolating major effects rather than complex minor ones.

From 1896-1910 the work at Cockle Park in Northumberland which was begun by Somerville and later carried on by Gilchrist was important. It concerned first the benefits obtainable from wild white clover in grassland and secondly how to encourage its spread by the use of phosphates such as basic slag. The value of legumes in arable cropping was known from Roman times and red clover was employed in the Norfolk Four Course Rotation just as the medieval manors grew pulses before wheat under the Open Field System. The nitrogen fixing properties of legumes were recognised as soil enrichment even if the mechanism involved or the chemistry was not understood. So it was that the value of encouraging wild white clover was quickly taken up all over the country and has remained established practice ever since. The period of the First World War saw a temporary shift of emphasis towards arable farming again but the recognition of grassland as an important part of British Agriculture was established. The founding of the Welsh Plant Breeding Station in 1919 marked a great step forward in the development of British Grassland Husbandry because it was from this source that the most important flow of knowledge came for the next twenty years. The team of scientists gathered there under the leadership of Stapledon, though intended by the benefaction which founded the Plant Breeding Station to concern themselves with Welsh problems, achieved far more. The findings at Aberystwyth were applicable to most of Great Britain and the strains of herbage plants bred and selected there have proved very successful in many parts of the world. The approach which Stapledon and his team followed was to ascertain the influence of environment and management on pastures. To study plant communities as an ecological problem was the basis and from this the interacting pasture-animal complex.

The plant breeding work was based on the selection of good parent material and the systematic breeding for specific qualities of leafiness and persistence from this material. The results of this part of the work were slower in materialising than the other studies but many strains of grasses and clover were available to British farmers before the Second World War.

The reason for the emphasis on qualities like leafiness was due to the research work in the 1920's of chemists like Fagan at Aberystwyth and Woodman at Cambridge and others at Jealott's Hill who established the nutritive value of herbage to livestock on the basis of chemical analysis. The need for minerals, protein and starch in animal nutrition had already been established. In this way the productive power of different plants in terms of animal nutrients quickly led to recognition of the most useful species and rejection of the worthless ones. The distinction between the value of leafage and stems was understood fully and so selective breeding for leafiness followed. The significance of different strains within a species came to light and so finally resolved the controversy of the value of perennial ryegrass. For a full generation graziers with old permanent pastures rich in this grass had known its value but those who sowed perennial ryegrass seed obtained a different type of grass plant. This was stemmy, short lived and as a grazing plant very poor. Hence two schools of opinion argued the merits of this grass each having experience of a totally different morphological plant. Until the idea of grass strains within a species was understood each with different growth characteristics both opinions were equally correct yet diametrically opposed.

In the Second World War grassland became vitally important in Britain. This was due to the increased land area under arable crops and the enormous increase that was demanded in dairying at the same time, from the reduced pasture acreage. The only possible solution to this situation was to achieve more intensive production from the remaining grassland acreage. This war-time food shortage set the pace in grassland production and utilisation which has not slackened since. Farmers came to realise the potential of their pastures and with improvements in knowledge of fertilisers and nutrition of both plants and animals more of this potential has been utilised than ever before. Since the end of the war ways and means of still further extending the usefulness of grassland have been explored. Articles in popular and scientific journals have discussed earlier spring grazing, later autumn grazing, winter-grazing and even all-the-year-round-grazing. Many other aspects such as increased yields, more intensive utilisation and improved conservation have also been explored with sustained vigour and considerable success. Not all the topics mentioned are entirely novel for early grass has been in stockmen's minds for long years past. Gilchrist in 1902 noted that the application of sulphate of ammonia produced an earlier flush of grass but if applied too early in spring produced no beneficial effect. In 1925 at Aberystwyth papers were published on the value of Italian ryegrass for winter grazing and spring grass production. While being fair to the past it is without doubt the very recent past in which most information on grassland has been accumulated. The quantity and quality of this factual knowledge has accelerated from year to year until now grassland science has become a specialisation in itself.

## II. SPECIES AND STRAIN SUITABILITY

The broad picture of the development of grassland husbandry sketched out in the last chapter serves to show how recent is its inception compared with other farming developments. Also, it shows something of the relative place in this picture of special purpose early spring production.

There is a deep conviction in the farming mind inspired by some writers and others that the use of the correct 'sort' of grass is the answer to the farmer's prayer for earlier grazing. This is a well based conviction though it is not based on the whole truth. Nevertheless it is important to consider the facts available relating to this approach.

As long ago as 1925 Stapledon, Fagan, Evans and Milton in a joint report on Aberystwyth work advocated Italian ryegrass for winter and spring grazing. They pointed out the losses which can occur due to winter 'burning' and that these could be reduced by grazing the herbage during the winter. To obtain the maximum yield of dry matter at a particular point in time, namely March, they advocated resting from October onwards until March but pointed out that much of the dry matter resulting was, by then, dead material. If, however, the maximum yield of dry matter was desired over this period then monthly grazing was the method to adopt.

Griffith and Jones (1932) described the success in Wales of wintering sheep using Italian ryegrass as a supplement to rough grazing. In 1935 Griffith further amplified this from an experiment using drilled Italian on a field scale and controlled grazing by hoggs. He compared the grazing days obtained from Italian ryegrass and timothy and was able to recommend the Italian for wintering purposes. Little widespread interest in Italian ryegrass seems to have followed this first enthusiasm at Aberystwyth. It was not until the end of the war that a few 'popular' articles began to appear dealing with the choice of early growing grasses. In a general article in 1948 Davies advocated reliance upon the ryegrasses for spring and early summer production.

Investigation of the growth curves and distribution of yield of ryegrasses through the season by Cooper (1949) revealed the high initial yields of Italian and Westernwolths ryegrasses in April though it also showed the drop in yield and quality of produce later in the season. Cooper distinguished between the perennial and the annual and biennial ryegrasses and pointed out the characteristic stemmy growth of Italian and Wimmera ryegrass. This stemmyness could not be modified even when cutting was at as frequent as fortnightly intervals especially with the Westernwolths ryegrass.

In 1951 and again in 1953 Davies wrote articles on grazing throughout the year thus indicating the stage which grassland enthusiasts had reached in their ideas on out-of-season grass production. The intense drive for more home-produced food was a real stimulus to such enthusiasm especially as it was about this time that the supplies of rationed meat-stuffs reached a lower level than they had done in war-time. The grasses recommended for late autumn and April were Italian and perennial ryegrass with S 143 and S 37 Cocksfoots in the mid-winter period of December and January and Timothy plus meadow fescue in February and March.

Towards the end of the war a new hybrid Italian was relaased by the plant breeders in New Zealand. This was a short rotation ryegrass resulting from the hybridisation of perennial and Italian ryegrasses and called H.I. This was bred specifically for New Zealand conditions to fulfil a need that existed there (Corkill 1954). It combined the best features of both parents, such as the very early growth and palatability of Italian with the persistency and relatively sustained level of summer yield characteristic of perennial ryegrass.

This grass was introduced to Britain after the war and appeared suitable for our conditions when used as an improved form of Italian ryegrass.

By 1953 Jones at Aberystwyth was able to indicate the performance of a new purely Italian strain, S 22, selected and bred for leafiness, in comparison with H.I. and ordinary commercial Italian. He found that in very early spring the two Italian ryegrasses yielded slightly more than did H.I. but H.I. gave a heavier hay crop. This follows Corkill's description of H.I. as a grass capable of more sustained production in summer than Italian ryegrass. The best qualities of S 22 appeared to be the ability to persist for two or three years and in those years outyield commercial Italian. Also S 22 Italian showed greater resistance to rust diseases in late summer than commercial Italian. Baker (1957) when propounding the grassland requirements for the production of April grazing quoted the results of a trial conducted by the National Institute of Agricultural Botany in which S 22 gave substantially higher yields of dry matter in the first week of April than commercial Italian and H.I. ryegrass. The respective yields were of the order of 1000 lb. of dry matter per acre from the former and 600 lb. per acre from the latter. At the same time he recommended the sowing of S 22 Italian ryegrass in August for grazing later in the same autumn and in the following spring.

The Italian ryegrasses do not entirely monopolise the spring season as perennial ryegrasses also have their place. Jenkin in 1930 first studied the characteristics of seasonal growth of perennial ryegrasses as part of the search for leafy grazing types suitable for parent breeding material at Aberystwyth. Several others have more fully developed this line of study with perennial ryegrasses, namely Hawkins (1950). He differentiated between the many local and pedigree strains on the basis of date of ear emergence. This established on a comparative basis the relative earliness and lateness of these strains. Heddle (1950) followed a similar approach but in addition to classifying on date of ear emergence he studied monthly yields from April to October and expressed each month's yield as a percentage of the annual total for that strain. By using his data it is easy to see that the so called hay types of perennial ryegrass are a type that can give useful early growth in April. The work of Beddows (1953) Heddle (1956) and Hunt (1957) further amplify this knowledge of the productive ability of the different perennial ryegrasses. None of these trials were concerned primarily with early spring growth. They give some indirect information but not as much as could be derived from trials aimed at this specific problem.

Charles (1955) is one of the few to conduct such a direct investigation of spring growth-potential involving several strains and species. His work was done at Aberystwyth where he compared firstly H.I., S 22 and Irish Italian ryegrass yields over three springs. The results were strongly in favour of S 22 especially in the second and third year due to its persistency. The same picture resulted when the comparison was extended to include S 24 and New Zealand mother perennial ryegrass and S 55 meadow foxtail. He gives the relative yields for these grasses as -

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|---|---|---|---|---|---|
| S 22 | Irish | H.I. | N.Z. Mother | S 24 | S 55 |
| 100 | 99 | 86 | 82 | 82 | 67 |

However, when the comparison involved S 170 tall fescue the picture was very different. In the first year S 22 outyielded S 170 roughly twice over. In the second year S 170 outyielded S 22 three and a half times over. Charles also did some comparisons between timothies involving overwinter resting but their yield responses though good, were inferior to the Italian ryegrasses.

This series of trials though small in scale are most valuable because they cut across the barrier of inter-species differences. This is a result of having early spring production as their primary aim and not merely as an indirect result of some other investigation. Like all good things there is neither enough of Charles' work nor does it cover as wide a field as one would like.

The idea of trying to find a clover which will grow early enough to provide spring herbage was studied by R.D. Williams in 1923. He had found subterranean clover very promising at Aberystwyth for this purpose so long as it had been sown late enough the previous autumn to prevent flowering that season. Subterranean clover plants still in the vegetative stage of growth proved winter hardy and able to grow early in spring. Seed however was expensive and being an annual was not easy to perpetuate by natural seeding in this country. The field scale establishment of this clover was tried in 1949 in East Anglia by T.E. Williams using Australian seed. Again, however, the total result was disappointing due to the lack of perpetuation of the clover. Its yield was far inferior to lucerne and the idea has dropped.

Williams in 1925 when investigating red clovers found that the broad leaved early flowering types commenced spring growth from 14 - 28 days sooner than the late flowering types. The actual bulk which can be produced is not comparable however with that of the grasses at the same date and so they play a small part in early spring production. The white clovers are no earlier than the early flowering reds and so the same applies here. In midsummer the direct importance of clover to livestock in grazing herbage lies in the high protein content of the clover leaf. This helps to balance the high starch and low protein content of grass at that time. In early spring this balance is not necessary since the grass fraction of the herbage is itself very rich in protein at that time. Often the content of protein is so high in spring that livestock cannot utilise it all and wastage results.

Of the other species available tall fescue is one which has created interest by its earliness in spring. Formerly, most seed was imported from the Rhine-land and supplies were of course stopped during the war. Since then imports have been resumed and an improved leafy type, S 170, has been bred in this country. Slowness in establishment and low palatibility at seasons other than spring restrict its adoption. Its total yield is not as high over the season as cocksfoot but its hardiness and extreme earliness give it a certain usefulness. Being perennial it is perhaps more economical to grow than autumn-sown rye seeded purely for spring grazing and possibly a silage cut before being ploughed again.

Among the recent introductions of foreign species to Hurley for trials and agricultural evaluation were several North African fescues which remain very wintergreen. Another species, Hordeum bulbusum from Italy has also shown winter green qualities which have led to it being subjected to field-scale trials (Cowling 1954). At the Cambridge Plant Breeding Institute thousands of cocksfoot plants mostly of Mediterranean origin are under scrutiny for winter hardiness features. Some of these show considerable promise and will be incorporated in future breeding material.

Meadow foxtail is always held to be an extremely early grass. It certainly is one of the first to show flower heads in late spring. It used to be sown frequently in permanent mixture for heavy land but as most seed came from Finland it ceased to be used during the war. A pedigree strain is now available but it has so far attracted little attention.

Tall oat grass is reasonably early but again seed supplies were unobtainable during the war since they came chiefly from France. Available strains seem inferior to cocksfoot in yielding ability. Breeding work is in progress on tall oat grass at Aberystwyth together with the hybridisation of reed-canary grasses. Unfortunately nothing significant can be expected from these sources for some time to come yet.

Cocksfoot, especially the hay strains of cocksfoot are popularly held to be among the earliest spring grasses but no authoritative comparisons with other species seem to have been made. Certainly not with the aim of assessing relative earliness of spring yields.

This serves to show the position with regard to the suitability of certain varieties for early spring production. Some of the knowledge on early growth potential stems from direct study of this feature as has been pointed out. The rest has been gained by very indirect means. Over the whole topic of special purpose spring varieties there hangs the promise of great possibilities, but rather of possibilities to come than of things yet achieved.

## III. NITROGENOUS AND OTHER FERTILISERS

The beneficial effects of nitrogenous fertilisers on spring growth have been known for a very long time in general terms. That is to say, in the past, by observation, it was noted that applications of such things as farmyard manure in winter gave greener and earlier spring grass. Farmyard manure was virtually the only form of nitrogenous manure available until the later Nineteenth Century when Peruvian Guano and sulphate of ammonia came to be used widely. At that period at Rothamsted, grassland experiments were conducted using sulphate of ammonia to note the effect on yield and sward composition. These and similar trials at Cockle Park revealed that repeated applications over several years produced little benefit to yield, a general reduction in palatability and the formation of a surface mat all of which were undesirable. The recommendations which had emerged by 1900 from this and other trials were that a complete fertiliser plus farmyard manure gave the most advantageous yield in terms of hay. Farmyard manure alone gave bulk but poor quality while phosphate and potash alone did not result in much extra quantity though quality improved. These trials were all carried out on permanent swards. Even with general purpose ley pastures the intensive use of nitrogenous fertilisers was found to be uneconomic. This was during a financially difficult period for British Agriculture and as the stock employed were fattening cattle the conclusions are understandable. The important fact that emerged from our point of view was that artificial nitrogen as fertiliser nitrogen was then called encouraged earliness of growth in spring. The timing of the spring application was also realised to be important and its effectiveness to be associated with the subsequent weather (Gilchrist 1902). Cold wintry weather if prolonged, following the application, was seen to nullify the benefits of artificial nitrogen.

In 1930 Fagan in the Welsh Journal of Agriculture was emphasising the ability of fertiliser nitrogen to improve pasture production and its protein content. This had been established by his analytical chemical work in preceding years. The power of fixing atmospheric nitrogen which clover possessed was of course known and its chemical nature understood. For this reason the stimulation of wild white clover in swards with phosphates and the inclusion of wild white clover seed in pasture seeds mixtures was standard practice by the early years of the present century. When endeavours were made to determine the effect of nitrogenous fertilisers on grazing stock eating the increased herbage produced, difficulties occurred due to the problem of evaluating the nitrogen return of the grazing animals. This problem has now been largely solved by the use of new techniques, such as by employing radio-active tracer substances (Raymond 1955). The problem of measuring the effect of nitrogenous applications is still not quite solved because it is now realised that such applications can diminish the clover in a pasture and so release extra nodule nitrogen.

Investigations were also made regarding the actual uptake of nitrogen by plant roots and it was noted that nitrates were absorbed quicker than other forms of nitrogen. Bacteriologists explained this by the nitrogen cycle whereby soil bacteria absorb non-nitrate forms of nitrogen and convert them in approximately three weeks to nitrates. In this form not only is nitrogen in the most quickly available form for plant absorption but at the same time it is the form of nitrogen which plants can use most easily. Fagan conducted much of this study of grassland and the effects of nitrogen upon it. The emphasis of his investigations was towards the effects upon dry matter and crude protein yields not only in spring but over the whole season.

It was in 1932 that a comprehensive article on fertiliser nitrogen was written by Watson at Jealott's Hill dealing not merely with the benefits from nitrogen applied during the summer but particularly from applications made in spring. The mid-season improvements were a general increase in total dry matter and crude protein yield and thus a more level production over the whole season. These mid-season trends continue after a nitrogenous fertiliser application with the maintenance of autumn growth at an improved level and an advance in the level of subsequent spring production. The magnitude of all improvements was, however, limited by climate.

At about the same time (1936) Blackman, also at Jealott's Hill, was studying the influence of nitrogen and temperature specifically in relation to spring growth in pasture. He found that the results obtained in early May over six years were very variable, due chiefly to the influences of soil temperature on the availability of nitrogen to the grass roots. The benefit in terms of date at which a sward reached grazing stage from applied nitrogen varied from as little as two days to as much as fourteen days. He found over a four-year period that a large percentage of ammonium and nitrate forms of applied nitrogen were no longer in inorganic form after ten days. Further, that an application of nitrate nitrogen only, increased soil nitrate content, while applied amide-nitrogen increased soil amide and ammonium-nitrogen but not nitrate. In view of the normal nitrification process by soil-bacteria converting ammonium-ions to nitrate this pointed to the direct uptake of ammonium-ions by plant roots. This ability has since been shown to exist in a range of plants most notable of which is paddy-rice. Most important of all was the relationship between soil temperature and growth. Blackman showed that 42°F was a critical point when measured at four inches depth. Below this temperature no growth took place although plant nitrogen content could increase due to absorption. Above 42°F growth occurred and applied nitrogen benefited the rate of growth up to 47°F. Above this temperature little difference was apparent. Clearly below 42°F temperature is the critical factor limiting plant growth while between 42 and 47°F the rate of nitrate release by soil organisms is critical. Above 47°F the rate of nitrate release is rapid and so the nitrogen supply is no longer critical. In any spring where the rise in soil temperature is slow and gradual the benefit of applying nitrogen is considerable since by making plenty available between the temperature of 42 and 47°F the limitation of inadequate available nitrogen is removed. When however, the spring is late and the rise in soil temperature is delayed the rise, when it does occur, will be sharper and take less time to increase from 42 to 47°F hence diminishing the advantage of applying fertiliser nitrogen.

Much more recently (1950) work done by Halliday at Jealott's Hill has shown similar results to Blackman's. One hundredweight of sulphate of ammonia per acre produced grass at the grazing stage from 3-13 days sooner than on untreated areas. The criterion of grazing stage in this case being taken as the production of 7.5 cwts. of dry matter per acre. Expressed in another way this quantity of sulphate of ammonia when applied in March gave an increase of from 20-90% in dry matter yield in early May. With 3 cwts. of sulphate of ammonia per acre the increase was from 80-200%. The temperature of 42°F, recorded 4 inches below soil level was again found to be the lower limit below which soil nitrogen was not made available to plants, but applied nitrogen was available down to a soil temperature of 35°F. However, although uptake is possible at this temperature little growth can be expected. Halliday concludes that by applying nitrogen to perennial ryegrass and cocksfoot swards in February or March grazing can be had as much as a fortnight earlier than on other unfertilised pastures. This figure of a fortnight has thus come to be the standard from which the fertiliser suppliers' claims are based in commercial advertising.

Ivins (1955) found a reduction of 15-20% in the dry matter content of herbage resulted when heavy applications of nitrogenous fertiliser were given, and when these were combined with high levels of potash this reduction could be 25-30%. However, the total yield of dry matter was increased in spite of this.

Baker (1956) in studying the effects of time of application of phosphate and phosphate plus potash on spring grass using a ryegrass sward found in all cases an improvement in dry matter and crude protein yield. In addition he found little difference resulted whether applied in autumn or spring. However, the difference in yield was slight compared to that produced by nitrogen. Autumn nitrogen gave only a slight increase in spring yield compared to the yield from the same amount of nitrogenous fertiliser given in spring. This was presumably due to the fact that it had produced its response in terms of extra yield in the late autumn and so there was little residual effect by spring. Sufficient residue remained to show a maximum spring yield when both autumn and spring applications were given.

In a later article (1957) Baker claimed an average gain in dry matter yield per acre of 100 lb. extra for each cwt. of nitro-chalk applied up to 4 cwts. per acre in April using a cocksfoot sward. This is a clear cut and relatively precise estimate of anticipated yields and shows the advance that has come about in this spring production aspect of grassland research.

A sidelight on spring herbage production is shown by Milton (1938) in tracing the effect of irrigation on the palatability of pure grown plots of grasses and clovers. In addition to his other findings he noted that irrigated swards grew earlier in spring than non-irrigated ones, and that this occurred irrespective of rainfall in the winter and spring. The result could not therefore be due to any limitation in available moisture. No nitrogen was applied but he concludes that the irrigation water had made more organic nitrogen available and possibly phosphate as well. He gives no basis for this presumption and though it may be correct the reasoning is not clear. This is especially so when one remembers that a wet soil is inevitably slower to rise in temperature and hence slower to reach the point suitable for maximum bacterial nitrification. Perhaps there is some other method by which nitrate can be liberated such as death of large numbers of bacteria due to anaerobic conditions and release subsequently of their cell proteins as nitrates. The fact remains that whatever the reason irrigated pasture is earlier to commence growth than non-irrigated. This was the reason for the practice of early flushing of water-meadows in Southern England a generation and more ago.

Heddle (1933) noted the benefits and improvements to hill pasture swards that occurred from flushing which is another expression for irrigating them. He quotes Hessleman(1917) who had found that flowing water improved oxygenation of soil and hence, due to extra oxygen, improved nitrification. This was, however, in summer time and may not be the exact explanation in early spring. The effects of irrigation on soil are certainly complex for pH is increased and the availability of phosphate and potash is also increased.

There is little evidence that fertilisers other than nitrogenous ones affect spring growth. Baker (1956) as already mentioned found potash and phosphate increased spring yield slightly. Corbett (1957) quotes Hart (1949) who stated that at $10^{\circ}C$ extra potash on a pasture increased its yield by 20% but, that at temperatures above $19^{\circ}C$ no difference was noticeable. The exact nature of Hart's experiment is not known as the reference was not obtainable but it would seem possible that potash could have an effect of this sort on yield. It is known to influence photosynthetic efficiency and hence the sugar content of cell sap. A relatively high sugar content is also known to be associated with frost resistance. This may in some measure explain the positive results Hart obtained at low temperature.

While an enormous amount of study has been done in the past on the effects of fertilisers on crops of all sorts including grassland only a small amount is related to the problem of early spring production. Currently, detailed studies to estimate underground transference of clover fixed nitrogen to grass are being conducted. The complication of nitrogen return when late autumn and winter grazing are undertaken is still not completely solved. This problem poses the question of the assessment of the value of the return of animal excrement at that period to spring production. Is this equivalent to defoliation plus spring fertiliser nitrogen or not, and if not how does it differ, and why? Such are the current problems and to solve them will be no mean feat. The benefits to earliness from applied nitrogen are however established, the limits of advantage both in time and yield are known. The economic value can be assessed and the approximate time of application is known. In short this aspect of early grass production is better understood than some others.

## IV. ESTABLISHMENT

It is important to know something of the establishment vigour of grasses used for spring production. Especially is this so when some of them are relatively short lived species like Italian ryegrass which might require to be freshly seeded each season. Whether there are times of seeding more suitable than others or methods of sowing which affect yield are factors worth exploring.

The difficulties in assessing actual field establishment are many. The germination power of the seeds used is a most important factor but, natural hazards like heat and cold, drought, fungal diseases, insect pests and so on play a large part in the final result. Davies (1926) encountered the effects of these hazards when he found substantially different values for establishment of grasses sown in the field compared to garden sowings. These were in turn different from laboratory trials. In fact the more extensive the scale of experiment, from laboratory on the one hand to field trials on the other, the greater were the hazards to the seedlings and the poorer the percentage of establishment. The results of the garden-scale trials occupied an intermediate position. Davies (1926) did find that though there was a difference between garden and field results the results for different species placed each one in approximately the same order for both trials. This shows that the increase in hazard is the same for any species of seedling.

He did find a high correlation between establishment percentage and seed size as measured by 1000 seed weight. The larger seeded samples gave the best establishment percentage. This held true between species and also between strains. On this foundation he was able to state (1928) that the ryegrasses have a potentiality for seedling development not exceeded by any of our British grasses. This at once has an important bearing on early grass production since the different members of the ryegrass family are the most widely used of the early grasses for spring production. It also means that the ryegrasses can compete very vigorously with other constituents of a mixture in the early stages of development of a sward. As there is a correlation between early spring vigour and seedling vigour young leys exhibit the characteristic of early growth in the first season or so. If these grasses are utilised by close and constant grazing at that period of the year they will be seriously weakened due to depletion of plant tissue. This process can change the character of a sward by imposing selective punishment to one section of the constituents. The result would then be the loss of the early growth characteristic which is so valuable. Expressing this in another way Davies (1928) maintained that the ability to stand up to competition in the first harvest year is a reflection of earliness of spring growth. That is to say early grasses if not closely grassed get an earlier start than the others and so withstand subsequent competition better.

Milton (1935) found there was a statistically valid difference between the establishment value of different strains of grasses except within Italian ryegrasses. On the whole commercial strains showed the most vigorous establishment and most rapid first growth but they are also the shortest lived strains within a species. He found ryegrasses the most vigorous species with Cocksfoot and Timothy much less so. Heddle and Herriott (1954) also found that the final plant establishment of ryegrasses was greater than Cocksfoot showing the great initial vigour of ryegrass yet again. They also found that the non-pedigree strains of both species gave higher final establishment figures than pedigree but they went further than this and showed final plant establishment was a function of seed rate. The lower the seed rate the higher was the final percentage establishment. This reflects the importance of seedbed competition between seedlings but with slowly establishing grasses the benefits to establishment percentage arising from low seed rates are offset by other adverse conditions. Chief among these is the increased competition from weed seedlings. Hughes (1951) found this particularly serious with low seeding rates of cocksfoot but less so with perennial ryegrass indicating a species variation in susceptibility to weed competition. This probably arises purely from differences in initial growth vigour. The desirability of high establishment percentages is in practice secondary to yield. This is controlled not purely by establishment percentage but by the number of plants established per unit of area which is quite a different matter. Economy in the use of seed is no excuse for a thin sward, for such a sward having a sparse plant population cannot utilise the available fertility to full advantage and so cannot give the best yield. The yield achieved is after all the final criterion of successful husbandry.

This aspect was further investigated by Heddle and Herriott, who established experimentally that in the early stages of establishment grass growth and yield were directly correlated to seed rates. Subsequently the yields and sward composition in swards of different seedling densities tended towards uniformity. The significance of this is that extreme economy of seed rate is undesirable for very short duration leys and also that the ryegrasses are the most suitable species to use for this purpose in view of their powers of rapid establishment.

Hughes (1951) obtained corroborating evidence in establishment trials with cocksfoot and perennial ryegrass. Increased seed rates gave increased numbers of plants per unit area and while with perennial ryegrass the establishment percentage fell as seed rate rose this was not the case with cocksfoot which showed little difference. He does not advocate low seed rates without making reservations about the species used and in general he holds low seed rates to be unwise for slowly establishing species.

Stapledon (1948) expressed concern at the differential effect the depth of sowing grass and clover seeds had on the ultimate composition of the sward. As all constituents of a seed mixture do not have the same ideal depth of sowing, any given depth will benefit the establishment of some constituents and handicap others. This is not as serious a problem as some other aspects of establishment because there is no uniformity of sowing depth achieved no matter how seeding is undertaken. To talk of a 'given depth' is to produce the vision of first something predeterminable and secondly something constant with negligible variations. Neither concept could be further from fact. When grass and clover seeds are broadcast very few seeds are sown too deeply and successful establishment usually results. If the seed bed is poor and rough or if severe drought follows seeding then broadcast seeds can suffer very badly. In drought-affected areas drilling is customary. This enables the seeds to be placed slightly deeper and so they suffer less from drought. The evils of over-deep sowing are then present and Stapledon's concern is well founded. The smallest seeds, such as clovers, can then be handicapped. Also, the extra crowding caused by placement in drill bands is an undesirable feature.

Stapledon advocates late sowing, that is from June onwards, for short lived species like Italian ryegrass. The aim in this case is to reduce the risk of flowering in the seeding year which maintains the full vegetative vigour of the grass plants into the first harvest year. If sown too late in the summer germination was retarded and establishment was found to be poorer. Martin (1949) found that the combination of cold and wet were the chief causes of this decline in establishment power and that fungal rot diseases also played a part in the case of legumes. He did not advise late autumn seeding of pasture legumes for, on the whole, their establishment proved unsuccessful if they were sown later than early August. Ryegrass vigour is again apparent from its ability to establish well from sowings made in August or September or even later (Stapledon, Davies and Beddows) (1928). Davies (1928) found that Italian ryegrass and tall oat grass were able when sown as late as October to give yields of hay in the following summer equivalent to plots sown six months earlier. This was a very remarkable result and would be very unlikely to happen in all parts of the country.

Stapledon (1946) stated the same thing in a more general way by advocating a pure seeding of Italian ryegrass for early and late season production as it could be successfully established over a longer period than any other species.

## V. RESTING AS A MANAGEMENT TECHNIQUE

In good pasture management one of the requirements for the maintenance of yield is periodic resting. This ideal came to be crystalised during the inter-war years as a result of the management studies at Aberystwyth. At that time several general rules became established such as the one involved in Moore's statement (1943) that it is desirable for every pasture to be grazed bare at least once each year. This principle of management was directed against the evils of 'mat' accumulation. Or again - "One essential principle for certain period production is resting as a pre-treatment" Stapledon (1946). This was based on the sound reasoning that if a plant is continually defoliated it is weakened, loses vigour and is unable to produce so much herbage. If the process of defoliation continues the most productive species in a sward can be killed out and serious deterioration of the sward's potential yielding power result. This is due to a form of selection whereby the less productive species are least punished and so survive and spread at the expense of other better species. Not only was this reasoning sound on logical and scientific grounds but it was an explanation of observed facts. The improvements in yield from periodic, rotational and strip grazing confirmed the wisdom of resting pastures. However, the matter is not so straight-forward when spring grass production is involved. At that time of year a sward is emerging from a natural period of rest and usually of freedom from grazing. Can it benefit from a modification or extension of this winter rest period? In other words does autumn and winter treatment act as a preconditioning to spring vigour?

By the deduction and reasoning approach already exemplified above it seems reasonable to expect similar effects from resting at all seasons with possible variations in their magnitude between summer and winter. This conclusion was firmly expressed by Jones (1933) who held that winter and especially spring growth was affected by the treatment of the previous season. Thus overgrazing in one season weakens the plants for the next season. As recently as 1956 E.T. Jones also declared that autumn and winter rest are needed for spring vigour else this vigour will be expended after defoliation in winter. As little plant activity can take place in midwinter due to climatic reasons it seems reasonable to expect that a longer rest period would be required than in summer. This was precisely the basis of Voisin's slide-rule-like schedule of pasture resting as a management technique (1957). In this the rest period is varied to suit the seasonal rate of recovery after grazing. This plan, like so many ideal programmes, is too inflexible to be practical and the effects of resting are not in themselves sufficiently uniform in any case. Davies (1938) observed that in a mixed sward composed largely of cocksfoot and ryegrasses the cocksfoot benefited most from a long autumn rest period and ryegrass most from a short rest period. The coarse growth of cocksfoot appeared to have a smothering effect on the ryegrass when the two were in competition.

The next problem was to know if the autumn growth should be left over winter or if it could be grazed off without reducing the sward's vigour. Is therein fact a point of time when growth has stopped, due to winter weather, when defoliation will have no effect on spring yield? It was not known whether the resting effect was cumulative from autumn until spring or not.

This was particularly uncertain in view of research such as that done by Tincker (1930) on the effects of defoliation on establishing cocksfoot and timothy plants in which he showed the effects could influence a whole season's yield. Davies (1938) in considering the yield from autumn resting for winter rather than spring grazing was concerned with 'winter-burn' or browning of the grass foliage. He found that if the resting was from July onwards the burning effect was serious by midwinter and palatability was reduced. Resting from September onwards, however, enabled the produce to stay green until February. Also, he found pedigree grasses yielded much more material and that of a higher nutritive value in winter than commercial strains. Stapledon (1926) claimed that Italian and perennial ryegrass, rough stalked meadow grass, crested dogstail and clovers were the most winter-green species together with certain herbs and weeds like daisy. Grasses such as Agrostis, fine leaved fescues, cocksfoot, tall fescue and tall oat grass were the most susceptible to 'burning'.

Corbett (1957) suggested that August 10th was about the latest time to start autumn resting for the best winter results but maintained that cocksfoot was the best grass species for winter grazing by store-cattle. He was thus thinking mainly in terms of cocksfoot when he spoke of August 10th. From the point of view of ryegrass Davies (1948) in an historical outline of in-situ grass conservation, comments "Ryegrasses on the whole, while they will grow actively in a mild winter do not conserve well if grown in the autumn and rested for winter use". He continues by saying that if the rest period is extended abnormally long then not only does the foliage turn brown and die in winter but the plant itself may even die as a result. Baker (1956) using S 24 perennial ryegrass found that winter-kill was directly proportional to the length of previous resting.

At this point there is perhaps a feeling of conflict between the benefits to spring yield resulting from autumn resting and the side effects produced by that resting, such as winter killing. The production of winter grazing as such is not the concern of this study but it is involved indirectly as a result of the production of herbage during autumn resting. The chief concern in producing spring grass is centred on the factors affecting its growth in spring. Conservation over winter in situ for spring grazing while perhaps possible, is not the purpose of this work. Nevertheless autumn resting does promote autumn growth, and if this is not wanted in spring due, for instance, to its death and loss of nutritive value in the meantime, then it must be removed somehow before that happens. What better method of removal could present itself than by grazing especially if it is in no way harmful to the subsequent spring growth. It is a cheap operation and affords stock good foodstuff at the same time. The problem is then to know at what point, if any, one can start grazing and stop resting knowing the full benefits of the resting treatment have already accrued. It is at this point that autumn resting, spring production and winter grazing are revealed as being inextricably intermingled. For the present it is sufficient to realise that this is so without separating the issues involved. It will be more convenient to re-examine the issues separately later.

There is a further complexity which has not so far been mentioned and that is the effect of combining autumn resting and the application of autumn-nitrogen. Such a combination could be expected to magnify any benefits obtainable to spring vigour by resting alone since it stimulates the amount of autumn vigour and this ex-hypothesi provides more for storage and subsequent spring use. Nicholson (1958) outlined the results obtained for a trial on a cocksfoot sward using three levels of nitrogen and two dates of application combined with different lengths of rest period. It is not quite clear from his report whether over-wintered foggage forms part of the spring yield or not. The spring yields were recorded in mid-May and though the trial was on a hill farm the results seem of doubtful interest here due to the lateness of the first cutting. He did claim a 23% gain in May yield from 40 lb. of nitrogen per acre applied in August without the addition of any subsequent spring dressing.

Corbett (1957) advocated 3 cwts. of nitro-chalk in August as an optimum economic application for winter grazing. He based this on the recovery of nitrogen in the autumn and subsequent spring herbage. The sward he employed was predominantly cocksfoot in composition and the heavier and earlier the autumn application the greater was the spring yield. In a point quadrat herbage analysis done in October he found 40% of the sward was cocksfoot, 30% was perennial ryegrass, 10% was timothy and 10% was wild white clover. In the foggage, yield as measured by dry weight showed that 65% of the total was contributed by cocksfoot and 30% by perennial ryegrass and timothy. The increase in yield of dry matter in spring from 3 cwts. of nitro-chalk applied in early August compared to the yield obtained with no nitro-chalk was 30%. This was measured in late May. The actual figures he gives were 1624 lb. of dry matter from the former against 1221 lb. from the latter.

In conflict with these results Hunter working at Boghall (1950-53) could obtain no conclusive results from autumn resting and no trend or pattern of results to indicate any advantage from resting. Baker in 1954/55 investigated the effects of autumn management and nitrogenous fertiliser on grassland and showed that different periods of rest in autumn had very little influence on herbage yields in the following spring. With regard to nitrogen when given as nitro-chalk at 3 cwts. per acre in autumn the increase in dry matter yield in spring was 17% compared to that from unfertilised plots. The same 3 cwts. of nitro-chalk applied in spring however, increased the spring dry matter yield by 50% while a double application of 3 cwts. in autumn and again in spring gave no more than the 3 cwts. in spring alone. These results were on good swards of mixed composition scattered all over England and so are reliable and not merely local in relevance. In 1955/56 he again found little benefit from autumn resting though some variations occurred between the swards. In both years the autumn weather was dry and the subsequent spring cold which would tend to minimise any possible gains to yield from resting.

There is thus a sharp conflict in the opinions of different writers on the effects of autumn resting. Prior to 1950 everyone seems to have been unanimous in declaring that autumn and winter rest was essential but few if any trials appear to have been conducted to prove it or measure the benefit. In most cases the opinions expressed appear to have been based on the effects of rest on production over the growing season as a whole and not specifically to early spring production. Now in the last few years when investigations have been conducted on the problem some have been positive and others sharply negative in result. Clearly there is a problem here worth pursuing.

## VI. GRASS ROOTS, PHYSIOLOGY AND THE PHYSICAL REQUIREMENTS FOR GROWTH

From the previous chapter it is evident that treatments such as resting have a very definite effect on the subsequent yield of a pasture in summer and possibly also in spring. To determine the means through which this act requires consideration of individual grass plants. Within a single plant the tillers are the units and so consideration must be focused upon them.

Since the leafage and top growth mostly dies in winter and as Green (1957) has shown the removal of leafage in winter by grazing had no effect on spring yields the plant bases and the roots must be the important zones of energy reserves. Jones (1933) in studying the effects of grazing on old and young swards concentrated on the effect produced on root and shoot vigour. By this means he was able to establish that winter and particularly spring growth were affected by the previous season's treatment. If over-grazing had been permitted then, vigour was reduced and the subsequent yield was less.

Another indication of interest in this aspect of grassland dating from the same period was in an article by Bates (1930). In this he recorded that root development and plant size was reduced on consolidated soil irrespective of species. He found that consolidation tolerant species had the ability to assume a rosette growth form. As an example he quotes perennial ryegrass as a species with this attribute. The basal nodes from which leaf and stem arise are situated below soil level in these grasses and so enable them to withstand grazing. In addition he makes two other assertions namely that in experimental techniques close and frequent cutting is no substitute for grazing since not only is there no return of animal excrement but more important the element of consolidation is lost. The treading effect of stock was in his opinion very important not only because it increases soil compaction but because it has a differential effect on different species. This arises indirectly due to the different tolerances to compaction but also directly to the differing abilities to withstand crushing by treading. He maintains that leaves which are rolled in the leaf-sheath like those of perennial ryegrass are better able to withstand treading than those which are folded.

The issues involved concern more than compaction alone even though compaction in itself affects plant growth in several ways. Soil moisture is important. Plants cannot grow without adequate moisture but there is an optimum for maximum growth potential. The more water soil accommodates the less air there is for root respiration. Kauter (1933) designed an experiment to test this and establish an optimum figure. He found that species varied in their optima for soil water but that most of the herbage species such as Italian ryegrass, meadow fescue and timothy had maximum root and shoot weights when the soil contained 85% of its maximum water holding capacity. When moisture is scarce it is shoot growth which suffers more than root growth (Bailey 1940). In areas of customary drought if the water-table is low but within the reach of plant roots, long roots will be developed to reach this moist layer (Jacques 1941). Cannon (1925) when declaring that oxygen was necessary for root growth declared that the greater the soil warmth the more oxygen was needed. Aeration has been found by Lamba (1949) to increase the weight of roots produced in the subsoil. This all corroborates Bates' observations on soil compaction but shows a more detailed analysis of the reasons. Kinoch (1952) found soil pore space increased with decrease in compaction and that root weights were greater in soil of high porosity than those which were compact. Clay soils and sandy soils have opposing qualities of denseness and looseness and so they affect the potential for compaction. In dry areas porosity can predispose the soil to dryness and hence limit plant growth for this reason while in a clay soil the close texture predisposes it to over-compaction and the lack of aeration that is so detrimental to vigorous root growth.

Of the soil factors pH is important. Neutral or slightly acid conditions favour plant growth most. In very acid soil it can be difficult to determine the effect on root growth due to the slowness of decay of old and dead roots. The low pH conditions inhibit the bacterial breakdown of dead root tissue and it becomes difficult to distinguish old roots from new or live from dead. Weighings of root tissue after a period of growth thus indicate the total weight of tissue present, since little has decayed, rather than the current balance of new tissue formed over old. Root vigour seems less under acid than normal conditions and foliage production is definitely much reduced.

One factor not yet mentioned which is of extreme importance to a plant's physiology is light. The influence upon photosynthesis of light is twofold. There is first the aspect of light intensity and secondly of light duration. For experimental purposes this can be controlled directly by applying artificial light in addition to normal daylight or indirectly by shading from daylight. Shading a grass plant from full sunlight reduces both its total growth and its root growth. Reserves are utilised under shading to produce extra leaf tissue and so root weights may even fall (Watkins 1940). Watkins also showed that a long photoperiod increased the dry matter yield of foliage, stubble, roots and rhizomes but foliage increased most. Mitchell (1954) studying the interaction of light and temperature on pasture ryegrasses in New Zealand found all aspects of foliage growth, elongation, new tiller and leaf formation took place faster in full light at 72°F than at lower temperatures. If plants were defoliated then recovery was slower with shading or with the higher temperature. The summer temperature employed is much higher than the British temperature even in summer. The importance of full sunlight is apparent however. Mitchell (1955) found that shading even the leaf bases reduced the rate of leaf tissue production and new tiller formation.

Very little information is available about the effect of light upon spring growth of grasses. Cooper (1950) published findings from work on ryegrasses concerning day length but the chief concern of this work was to discover the effect of day length on flowerhead production. While this was very valuable work it bears little relevance, to the strictly vegetative growth desired for early grass production. Langer (1954) is the one person to come nearest to considering the direct effect on leaf growth of light. His study concerned timothy plants grown out of doors in winter and in artificial warmth under glass. Not only did new leaves appear much more quickly with the warmth but their total size as shown by area of leaf surface, was about $2\frac{1}{2}$ times greater. When additional lighting was provided still further significant increases were obtained. This shows that under the conditions of this trial temperature had been at least as great a limiting factor as light. He concentrated his study upon the unit of the grass plant namely the tiller. His results show that the two factors of heat and light markedly affect the winter growth of timothy. There is no indication how other grasses would have reacted to the same treatment. It could well be that some grasses are more sensitive to light than temperatures or vice versa and that some can grow vigorously at lower temperatures than others. Such information would be invaluable in choosing grasses for spring production. Selection for this quality could be the basis of a special purpose strain designed for vigorous winter and spring growth. Before anything as remote as this could be contemplated the work begun by Langer needs extension to cover existing grasses about which nothing of this sort is known.

Stapledon (1930) studied roots and shoots to discover the effects of different cutting and manuring treatments. Using spaced plants of indigenous cocksfoot he found a progressive increase in foliage, root and tiller development from April to October when unhampered by cutting. Applications of nitro-chalk increased the development and yield of all three. Single applications had little effect except on foliage. Only repeated and heavy applications increased root and tiller weights. He found that the more lenient the cutting was and the less frequently it took place, the greater the total yield of forrage in the season. Later work by Jones (1934) confirmed the effectiveness of this method of maximising the yield of herbage for cocksfoot but indicated that other species such as the ryegrasses did not respond to this treatment as well as cocksfoot. They yielded most when subjected to treatment resembling grazing such as close and periodic cutting. The cause of such a fundamental difference would seem to arise from the totally different morphology of the two plant types. Roberts (1936) declared that root growth, quite apart from foliage growth, is checked by all types of foliage cutting and is proportional to severity.

The actual weight increase of roots was checked due to transference of reserves to produce new photosynthetic tissue. These reserves become exhausted if cutting is too frequent and then, not only does the normal root weight-increase stop but a positive loss of weight takes place also. The lengthening of the roots is also checked and their growth rate suffers. He states emphatically that in perennial ryegrass storage is in the roots which he suggests accounts for the survival of this species in closely grazed pasture. In timothy, on the other hand, storage is at soil level in the bulbous plant base. Close cutting and the strain of flower production cause a reduction in the weight of perennial ryegrass roots but not of timothy roots, indicating the source of stored energy is dissimilar.

A further statement of the issues involved came from Weinman (1948) who said that roots and underground rhizomes of grasses were used as stores for carbohydrates plus nitrogenous and mineral compounds which are utilised in spring. He held that soil type and available moisture influence the extent of the storage, while defoliation limits storage by reducing the ability to create a surplus. Excessive defoliation reduces reserves and weakens the plants which can cause suppression of those plants by other species so producing sward degeneration.

Baker (1957) using S 24 ryegrass also found that cutting the foliage caused a reduction in root weight and the more frequent the cutting the greater the reduction in both root and shoot weights. In spring this causes a reduction in the rate of subsequent shoot growth for a time. The cut shoot still continues to grow but at a reduced rate. As a result the total yield over a given period is greater from uncut plants than from the first growth and regrowth of defoliated plants. If the cutting is done in August or September the effects on the root and on the shoot weights are still noticeable in the following spring. The root and shoot weights all fall naturally during winter due to reduction in carbohydrates in stubble and roots at this period. In a subsequent article (1957 III) Baker showed that herbage growth in February and March was not correlated to root weight per unit area in the previous autumn but was directly proportional to root weight per plant. The maximum early spring yield was obtained from leniently treated autumn plots where low plant and tiller densities had produced a relatively high root weight per plant and per tiller. In April the rate of herbage growth was for this reason inversely proportional to sward density. Slightly later the results showed yields to be directly proportional to density while in late May and June it was again inversely proportional probably due to competition by then between tillers for moisture and available nutrients.

Troughton (1956) established a mathematical relationship between root and shoot weight in young grass plants which remained roughly constant except at flowering time when shoot weight increased relative to root weight. There were different values for different species but all tended to retain their own constants. While population density affected the size of individual grass plants it had little effect on the relationship between root and shoot weights. Applications of Nitrogen fertiliser upset the relationship by increasing shoot-weight more than root-weight.

Lest it should seem that root growth is always producing an increase it should be pointed out that there is a cycle of increase and decrease involving growth and decay in grass roots as in grass foliage. The cycles of root and shoot do not, however, coincide. Troughton noted an increase in root growth in late summer that continued actively until midwinter and therafter slowly until spring. Troughton (1951) found the root weights of mature swards were least in November and greatest in May indicating winter growth. There is a slow rate of growth in summer and a drop in root weight just prior to flower-head emergence when reserves are being transferred for flower production. In most cases hot weather in summer is unfavourable to root growth.

The close study of roots is made difficult by the death of old roots as well as by the production of new ones. It is difficult to know exactly how long an individual root lives but Stuckey (1941) found this depended partly on species. Some grass species replaced their entire root system each year while in others a root may serve for several seasons.

In relation to storage of carbohydrates Troughton statés that once a grass plant is established it seems to store carbohydrates in its roots during periods of slow herbage growth in spring, summer and especially autumn. These reserves are then used during periods of rapid herbage growth and for initial herbage growth in spring as well as for respiration and growth in winter. If the plant is defoliated at any time these reserves are mobilised irrespective of season for the production of new leaf tissue. He found carbohydrates reserves lowest in early spring when the most active growth begins. This is due to the utilisation of most of the previous autumn's accumulated reserves for new root growth and the commencement of leaf growth.

The trend with nitrogen and minerals in the plant tissues was found to be similar to that for carbohydrates. The reserves reach their highest level in late autumn when translocation to the roots and plant bases of soluble nitrogenous substances takes place. These reserves diminish rapidly from May until July (Arny 1932) and then recover again between July and November. Sullivan and Sprague (1943) found that partial defoliation of Lolium caused the transference of the soluble carbohydrates only for new leaf production. Also, that a period of three weeks elapsed before the plants made good their lost tissue and once again began to accumulate carbohydrate reserves.

Some extremely detailed experiments have been carried out on the topic of defoliation - effect upon a grass-plant's physiology. For instance, Crinder (1955) found that when more than 40% of the total foliage was removed in one operation artificial root growth ceased within twenty-four hours and the length of time required for recovery varied directly with the severity of the defoliation. Roberts and Hunt (1936) and others have shown that the loss in root weight subsequent to defoliation was proportional also to the amount of foliage removed. Crinder found that single tillers acted independently to the rest of the plant, behaving as self-contained units. He too found that the effects of defoliation suppressed root growth longer than shoot growth since the defoliated plant mobilises its reserves to produce new photosynthetic tissue. Only after that has been achieved do the roots show recovery. If the new leaf tissue is again removed before the root reserves are replaced then the effect of the two defoliations on the plant as a whole are combined. If this happens too frequently the plant may be so weakened that it dies. In the practical application of this, rapid grazing of a limited area followed by resting as in 'strip-grazing' is seen to be based upon a sound and scientific basis. It is apparent too that plants can be more susceptible to defoliation at different seasons due to the varying amount of reserves they have stored in their tissues. In spring the first growth results from mobilised reserves. If this is immediately removed the plant is more susceptible to exhaustion than later in the season when other factors such as weather and available nutrients are more helpful towards recovery.

The height of cutting and frequency of cutting are two factors so closely involved that they are virtually interchangeable. The effect upon the plant of lower cutting can be offset by less frequent cutting and vice versa. In practical grazing management the height and degree of defoliation is not controllable as in experimental work when cutting is employed. The proportion of the plant's total leafage which is removed has been shown to be important. Different species have contrasting growth habits. An upright habit allows easy defoliation by stock which can result in a far higher proportion of the plant's total leafage being removed than if it is in a prostrate type. The truly perennial species and strains of grasses are predominantly prostrate and these are able to survive and persist by virtue of this feature. There are differences in tolerance to defoliation within even the upright growing type. Molinea caerulea cannot resist even moderate grazing or cutting while cocksfoot tolerates both well. Klapp (1937) has suggested that this is due to the length of time which elapses in summer before Molinea begins to accumulate reserves. There is thus a prolonged period during which this grass is vulnerable to the effects of defoliation as it has little food reserves in its basal tissues. For this reason if for no other Molinea is not a good pasture grass. This feature is in a way analogous to the different time taken by early and maincrop potatoes to form new tubers. When planted at the normal time early varieties will have almost completed tuber growth by early August while maincrop varieties will have only begun by then.

Troughton (1951), by means of vertical cores established that 90% of a sward's roots are in the top six inches of soil and 96% in the top twelve inches. These are however average results and many factors can influence these proportions. Several authorities (e.g. Davies 1954) have declared that 'hard grazing', that is severe and constant defoliation, is inconsistant with deep rooting. Klapp (1943) found that defoliation reduced the weight of roots in the lower soil layers to a greater extent than those in the upper layers which bears this out. Rhizomatous grasses seem to have a reaction similar to the rest in this respect for Harrison (1931) found that rhizome weights, like root weights, are reduced proportionally to the defoliation severity.

If instead of part of the foliage being removed part of the roots are removed by amputation the shock to the plant is not so severe as defoliation. Food reserves do not have to be translocated or transformed in any way. The means of producing new plant tissue remain intact in the form of the leaves which do not have to be replaced first as after defoliation. The repairs to the plant are thus effected out of 'current income' and not from 'capital reserves' of energy. If the root or roots concerned are young the response to amputation is seen in the rapid formation of new laterals. The number of these depends on the length of root remaining on the plant.

Both root and shoot weights are reduced by defoliation. The shoots by virtue of removal of tissue and the roots by the transfer of soluble food reserves to renew the lost foliage. The effect of this weight reduction lasts much loner in the case of the roots than the foliage so that it is a considerable time before the original balance is restored between roots and shoots after defoliation.

The condition of grass roots in soil low in available nitrogen is also characteristic. Under such conditions the roots are much better developed than when nitrogen is plentiful but with low nitrogen shoot growth is poor. With plentiful nitrogen the opposite is true. When a single application of nitrogen is applied to plants which previously did not have excess nitrogen both roots and shoots show an increase in growth but the shoots do so the the greater extent. This also produces an alteration of weight ratio. The cause of the extra growth by the shoots rather than the roots is probably connected to the carbon/nitrogen ratio within the plant. A close ratio always stimulates vegetative growth. Durrow (1939) compared nitrate and ammonium nitrogen effects on grass plants in sand culture. Both forms were absorbed by the plants but those receiving nitrate-nitrogen showed much better development.

Phosphate applications used to be thought specifically beneficial to plant roots. However, phosphate benefits the whole plant and the differences in ratio of root and shoot weight caused by phosphate shows no consistent trend. Reid (1933A) also found high soil calcium encouraged root growth. On the whole it can be stated that if pH is near neutrality and no single element is limiting plant growth and development then extra nitrogen has a greater effect upon it than any other element.

One effect of temperature upon plant-growth has already been mentioned in connection with soil nitrification. Low temperatures have of course other effects. Frozen soil can subject the plant to drought conditions and prevent growth, plants can be loosened by soil heaving with loss of anchorage when thaw returns. Foliage can be killed by cold and even tillers may die as a result of it. Soil temperature fluctuates less than air temperature so that in autumn the soil is usually warmer than the air and vice versa in spring. For this reason it is common in horticulture to find soil warmth being increased in winter and spring using electric heating cables under the soil surface. A number of soccer and rugger pitches are now being kept frost free by this method. The sports turf research association's station near Burnley in Yorkshire is examining the scientific aspects of this. So far tests have merely shown that this measure is feasible and economic for sports purposes but the extra warmth is maintaining a drier soil and a more vigorous sward. It is not likely that this will ever be economic in farm practice but the research that it is promoting will certainly increase our knowledge of the physiological aspects of temperature in relation to grass growth in winter and early spring.

Closely related to temperature is the effect of wind on grass growth. No attention has been paid to its direct effect on grass growth. Indirect attention has been paid by ecologists like Tansley to its effects on plant life in general but not on grass in particular. Wind is recognised as adverse to plant growth if too strong or too constant. Williams (1951) and Cowlishaw (1951) both found the effects of shelter increased the yield of grasses. They were concerned with measurement techniques in trials that used protective cages. Under the wire cages temperature, humidity, wind force and even light intensity were altered so that the cages provided a microclimate more advantageous to the grass sward's growth. This proved distrubing to those who had used cages as a means of pasture growth measurement during grazing trials but it emphasised the effects of microclimate.

Caborn (1956) working on tree shelter-belt problems showed how natural shelter can affect wind velocities and humidity. He did not try to measure the effects upon crop or grass yields. Various foreign sources have devoted much attention to the benefits of shelter from trees. Denmark and the Ukraine are two areas where extensive tree planting has been undertaken primarily on account of its beneficial effects to crops. Neither region is concerned with pasture production to any extent but rather with cereal growing. Crop yields in those areas are increased by the tree-shelter due to direct protection from physical damage by wind. Also, the indirect benefits of a less steep humidity gradient between the crop plant and its surrounding micro-environment caused by the reduced wind velocity which reduces transpirational losses and promotes the higher yields. For early spring grass production the benefit of such shelter would probably not be due to humidity so much as increased temperature resulting from lowered wind-force. As temperature is all important in spring and surface cooling of the soil by wind undesirable, shelter is worthy of more attention than it has had so far in this country.

## VII. DRILL-GROWN GRASS

Among the various techniques used in the production of grass for special purposes that of growing it in drills is one which offers some special advantages. It was found at Hurley that cocksfoot grown in drills two feet apart for seed production could be grazed down in late autumn without detriment to the grass drills. It was observed that while the cattle would graze the drills very closely they did no damage by treading as they walked between and not upon the drills. It was found advantageous to graze in this way as it served to remove unwanted leafage more thoroughly than by burning. Also, the excrement of the cattle was of more value to the grass than the ash from burning. Green (1957) remarks that grazing in December clears away rubbish and allows light to have its full effect upon the growth primordia in spring. It also serves to reduce over-dense tillers which, due to over-competition, seed badly. Tillers which are grazed down in December have time to develop before spring. Green found this was reflected in improved yields from seed crops of S 143 cocksfoot, S 215, S 170 and S 59 fescues which had been grazed in December. If the grazing is prolonged during the winter until March then the vigour of the grass plants is reduced by the constant defoliation and loss of reserves. The time left to develop strong flowering parts is so reduced that seed yields are diminished. Thus the disadvantages of prolonged winter grazing offset the advantages of removing autumn growth.

From this by-product of seed production the idea of growing grass in drills specifically for grazing has developed. Green found that the grasses yielding most dry matter in autumn, winter and spring when drilled were cocksfoot and then S 170 tall fescue. Gardner(1958) also declared cocksfoot the most suitable species for foggage production. Timothy and meadow fescue yielded less than cocksfoot and perennial ryegrass was found to suffer from winter-killing when in drills. Green found broadcast plots of cocksfoot yielded more than drills while Gardner found that over three years the total dry matter from cocksfoot was more from drills than from broadcast plots. He also noted that the average losses of dry matter in winter over four years were 17% for cocksfoot, 34% for perennial ryegrass, 18% for timothy and 24% for meadow fescue and that broadcast plots of all species tended to have approximately 11% greater loss of dry matter than drilled plots. He found no significant difference in summer dry matter yield between drills and broadcast plots for any species.

Consideration of drilled grasses can be tackled from two approaches. The growing of grass in drills specifically for autumn,winter or early spring grazing in situ offers some advantages and some disadvantages. Where treading can do serious damage to pastures as on certain soils, drilled perennial grasses could be the alternative to constant re-seeding of short duration swards like pure Italian ryegrass. Herbage in drills grows strongly and offers a drier and more airy plant environment than a broadcast sward. On the debit side there is the problem of establishing and maintaining a widely drilled sward. Weeds can be a serious problem especially weed grasses and the provision of legume nitrogen is difficult. Alder (1954) has suggested sowing clover between the grass drills but its survival between any but widely spaced drills would be difficult and the presence of clover plants would make weed suppression more difficult. By substituting lucerne for clover certain of these disadvantages are overcome. Lucerne is suited to cultivation in drills and at the same time is a legume fixing atmospheric nitrogen by nodule bacteria. Alternate drills of lucerne and grass are quite feasible and have been used at Hurley to provide good quality silage cuts in summer and winter grazing. This systematic partnership of grass and legume is just as successful as grass and clover in a mixed broadcast sward. The only question that remains unanswered is whether or not the yield so obtained is worth all the extra trouble.

The other aspect of drilled grasses which is very important is, that for experimental purposes grasses are often grown in drills. Comparative results within a trial are obtained but without some idea of the relationship between the results obtained from the drilled grasses and broadcast plots much of such an experiment's value cannot be translated directly to practical agriculture. Milton (1936) tackled this problem by growing a total of five strains of three species broadcast and at different drill widths from twelve to twenty-four inches apart and comparing the yields. He found that the two feet wide drills gave more of their total annual yield in the first, early spring cut than the broadcast and that there were differences in species response. Perennial ryegrass when in drills yielded most at sixteen inches spacing but most of all when broadcast. Cocksfoots tended to be best at twelve inches while timothies showed little advantage between close twelve inch drills and broadcast plots. For every drills width used, cocksfoot gave the highest individual dry matter yield at that spacing. This confirmed the suitability of cocksfoot for drilling expressed earlier. Tall fescue was not included in the trial but it might have been expected to behave similarly to cocksfoot.

It is important to realise that comparative trials using different species in drills not only gives less or more yield than in broadcast sward but some species and even strains are more favoured than others by the technique. It is usual to point out that the results of a trial are limited by the conditions of the trial. It is of added value when the trial is of such a form that the results can be used as a basis for deductions and further trials. The gulf between the results obtained from drilled trial plots and broadcast plots is therefore more than ordinarily wide at present and to bridge the gap would be a useful scientific achievement..

Fagan (1933) found that even the chemical composition of drilled and broadcast herbage differed. In drills the stem to leaf ratio was narrower but as the nitrogen content of the herbage was higher the extra nutritive value balanced the extra stemmy-ness. Potassium content was also consistently higher in drilled herbage and calcium content was lower.

More recently attention has been focussed on other aspects of nutritive value. Hughes (1948) analysed the proportions of a broadcast sward's herbage which were live and dead in January and determined the crude protein content of both. He found that by January 86% of the herbage was dead matter but even then the overall crude protein percentage was 8.8% being thus equivalent in nutritive value to average quality hay. Dry matter yield he gives as 30 cwts. per acre. Corbett (1956) also provides indications of yield claiming 150-200 store bullock grazing days per acre in winter from cocksfoot swards and 100-150 days from perennial ryegrass and timothy. These figures fell as winter progressed. By midwinter the percentage loss of organic matter for cocksfoot was

10-20% but for timothy was approximately 30% and for perennial ryegrass was 40%. He attributes the greater keeping quality of cocksfoot to its low ground coverage. Approximately 30-35% of the ground area under cocksfoot was bare of vegetation. This openness allows more air circulation than in the short, close herbage of a perennial ryegrass sward. In a subsequent article in 1957 he advocates cocksfoot again, on account of its greater stock-carrying capacity. Though stock consumed more perennial ryegrass and timothy than cocksfoot they gained less liveweight as the material passed quicker through the gut. Utilised starch equivalent from cocksfoot plots obtained totalled 32 cwts. per acre. This compares well with the national average of 16.7 cwts. per acre per annum. He claimed that the loss of nutrients from foggaging was approximately 20% while the ensiling process on average caused losses of 25%. The losses from foggaging are obviously dependent on the dates of utilisation. The longer the material is kept the greater are the losses which is not the case with ensilage. Gardener (1955) at Auchencruive also advocated cocksfoot for grazing until December. To maximise the yield, resting from August onwards was necessary. He found that an August application of 3 cwts. of nitro-chalk per acre was the optimum economic fertiliser dressing to combine with this resting period. He too found a serious fall in the nutritive value of herbage kept after December.

The system of foggaging is thus not suitable for overwintering large quantities of nutritive material.

Corbett (1957) remarks that foggaged pasture continues to grow later in autumn than normal swards and suggests this is due to the insulative properties of the herbage to the soil. He found that foggaged pasture started growth earlier in spring and yielded grass between two and three weeks sooner in addition to having given grazing later in the previous autumn. Gardener noted the same effect and concluded that it was due to the long autumn rest from August to December. This is certainly the chief cause but the fact that cocksfoot was the grass employed is undoubtedly another significant factor. Lazenby (1957) probed the underlying causes of the differences in performance when grass plants are grown at different spacings. He was chiefly concerned with perennial ryegrasses. He found that the maximum yield per unit of land area was obtained from a broadcast sward and least from spaced plants. While this applied to the total yield over a season it did not apply to each cut during the season. What was revealed was that differencesbetween the yields of different strains were greatest when they were grown as spaced plants and least when in broadcast swards. In a further paper Lazenby (1957 B) points out that factors which can limit plant growth such as low temperature, affect spaced and broadcast plants equally. Other factors like drought show up quicker in broadcast swards due, presumably, to the greater competition between the individual plants. This can result in alteration of the seasonal yield or growth curves since a more uniform yield is obtained from spaced plants. This explains why broadcast plots did not always outyield spaced plants in individual cuts during the season. He also found that the effects on yield of management variations was less with spaced plants than broadcast swards. In all the above he found drilled plots represented an intermediate position to broadcast plots and spaced plants.

From this it will be realised that while widely drilled grass grown for grazing is perfectly sound practice and is being used for autumn and winter cattle grazing its application to spring grazing needs more investigation. At present there is no basis for recommending or condemning the idea absolutely because so little has been done on the subject.

With regard to experimental techniques it is clear that the chief difficulty lies in the translation of results from broadcast to drilled conditions and vice versa. This is due to the large number of environmental factors which are involved and the influence of them on the plant's physiology.

## VIII. NUTRITIONAL VALUE

To evaluate a grass by its productive ability is not only a common sense approach but is the most accurate method available to us. This is straightforward if the evaluation is in terms of herbage produced but it becomes difficult when it is a secondary product like live-weight increase that is measured to evaluate the herbage productivity. Yet it is desirable to try and use this basis since grass in itself is not a saleable product except in so far as it produces animal products which are marketable. The problems of conducting trials with livestock are legion. It is difficult to have many replicates, there are variations between individual animals which are difficult to overcome with the small numbers employed, maintenance requirements must be calculated and mutton or milk has to be translated back to an energy requirement to assess what the sward is yielding. Over all else is the problem of knowing how efficiently the available herbage has been utilised. These difficulties have gradually been faced and provision for them is made in present day trials.

In the Nineteenth Century when animal foodstuffs were first assessed nutritionally it was chemists like Kellner who devised the methods and obtained the first true results. These did not concern grass primarily and the stock were mature fattening steers. At that period many chemists sought to solve the problem of nutritional values on the basis of mineral analysis. Enormous labour was devoted to meticulous analyses of the inorganic components present in foodstuffs. It was almost as if they were hunting for the key to their problems by checking all the impurities, which was a method that had yielded results in industrial chemistry. This form of analysis was subsequently of minor importance to animal nutrition but it marks a stage in its progress. It was the age of the inorganic chemist. Organic chemistry superseded this in the realm of nutrition and it in turn has yielded to the specialisation of bio-chemistry. This last has devised the special methods necessary to handle enzymes, antibiotics and complex vitamins which were unknown in the Nineteenth Century. It was from the foundation work of chemists like Kellner that it was possible to progress to the current evaluation of feedingstuffs by starch and protein equivalents.

At the beginning of the Twentieth Century it was thought ideal stock-husbandry to have cattle grazing knee-deep in herbage as this indicated generous treatment. Now under our strictly financial economy and our increased knowledge, this approach is radically altered. The change has come about chiefly by the realisation that the nutritive value of grass-leaf is far superior to stem. This was clearly stated by Fagan and T.H. Jones in 1923. They showed that the difference in composition was least in spring and greatest in the later part of the season and winter. They pointed out that the superiority lay in the greater amount of protein and less fibre and the higher ratio of true to crude protein in leaf than in stem. Stemminess obviously increases as flowering approaches but this analytical approach showed the nutritional implications of this. Stapledon (1930) using Italian ryegrass was able to express the protein difference by a ratio, stating that the leaf was twice as rich in protein as the stem. Usually the grasses which yield the greatest bulk also give the most nutrients. (Ibid) To maximise the annual dry matter yield of some grasses such as cocksfoot, infrequent defoliation is required. (Jones, Ll. 1937) This example however, is contrary to the requirements for producing the best quality of grass per unit of quantity, since all new growth is more nutritious and more digestible than old. (Fagan 1930) This is so because lignification of both leaf and stem tissue occurs as it ages. As a compromise Stapledon (1930) advocated lenient grazing for young swards and more frequent grazing for well established swards. In more recent times this has been embodied in the advocay of rotational and strip-grazing. This aims to give the optimum quantity of yield consistent with a high quality.

From a stockmanship point of view palatability is also critically important. The most nutritious grazing is worthless if stock will not eat it. Equally important is the realisation that the relative palatability of plants cannot be judged by any empirical means. The ultimate choice lies with the grazing animal. Some classes of stock are known to be more discriminating than others and mature animals more so than young growing ones within the same class. However, in general, palatability is a function of plant growth stage. (Fagan 1930) There are exceptions to this but the older plant material becomes, the tougher and more fibrous it becomes and this is directly responsible for the loss in palatability. By considering how much quicker some grass species reach the flowering stage than others it is easy to appreciate how those plants will remain palatable for a relatively shorter time. At the same growth stage palatability may be equal but the duration of the different growth stages varies greatly. This concept of growth stage may explain the varying palatability of one species at different times but it does not account for different degrees of palatability between different species. Harsh dry-textured plants are less attractive to stock than succulent ones and leaf is more attractive than stem but this is not the full story. Why is it that a grass like meadow foxtail though leafy and highly nutritious is unpalatable at all times and at all stages of growth? Clovers, other than wild-red-clover, are on the other hand relished more than grasses all the year round. Crested dogstail, a small narrow leaved low growing grass is most attractive to sheep at all times except when flowering. (Davies 1925) There are herbs like millfoil and chicory which are liked too. Why? In all these cases leafiness, succulence, stage of growth, absence of pubescence, habit of growth and range of choice affect an animal's selectivity. Some herbs are rich in minerals and, this seems to contribute to their attraction. This is possibly a case of attractive flavour being the decisive factor in selection. Grasses with an upright growth habit are more favoured than those of prostrate habit due to the greater ease with which stock can browse them. In wet weather stock will select more fibrous material and more lush material in dry weather. It is clear that selection is on the basis of palatability and this is only incidentally linked to nutritive value. The example of the neglect of meadow foxtail, though highly nutritious, is an example of this.

In the same way that the palatability of a normal grazing species is largely an expression of the plant's growth stage, nutritive value is affected likewise by growth stage. Due to lignification as plant tissue ages it becomes less easily digested and its nutrients less available to stock. A further complication creeps in when stage of growth is adopted as a criterion of quality. Woodman (1934) showed that grass leafage grown in the second half of the summer, that is from July onwards was poorer in protein, calcium and phosphoric acid, but richer in fibre and nitrogen-free extractive than spring-grown grass leaf.

Its digestive and nutritive value was also poorer suggesting that lignification had occurred quicker. Woodman thus came to the opinion that stage of growth is not a valid measure of chemical composition and digestibility of pasture herbage. Meteorological conditions too, are important in that they affect the rate of growth and the rate of lignification. Winter cold is analogous in this respect with summer drought, except that drought conditions increase the calcium content of herbage while frost decreases it. (Ibid 1934) This variability of nutritive value within a given growth stage under different seasonal and climatic conditions gave much concern but was overcome by the concept of physiological age.

This concept aimed at accommodating all the conflicting forces already mentioned which affect the quality and nutritive value of pasture. The actual age of the material, the conditions under which it was grown, the weather effect and the rapidity of tissue formation are all accommodated in this concept of physiological age. Tissue may remain a longer or shorter time in a given physiological stage the duration depending on the external factors mentioned above and on the internal forces directing the plant growth towards vegetative or reproductive increase.

In early spring all growth that occurs is highly succulent and stock which have been living on conserved foods during winter find it highly palatable. It is also highly nutritious. Featherstone (1951) studied the gradual changes that occur in the yield and the chemical composition of grass herbage from early April to June. He found that total yield based on dry matter yield was a reliable guide to output. This, as would be expected, showed a rise as spring growth increased from April to June. In the same period there was a corresponding decline in crude protein percentage from 26% in the very leafy material to 7% when flowering occurred. As the crude protein decreased the crude fibre increased and the digestibility fell. As a guide for obtaining the optimum yield of dry matter and protein Featherstone recommended cutting at five to six-weekly intervals. When thinking of grazing only it is known that the very youngest grass is so rich in crude protein, being over 20%, that much of this is wasted as the stock cannot utilise it. Watson (1951) points out that while early grass is low in fibre and hence low in dry matter percentage this nevertheless increases in time, but after the first three or four weeks it has only risen slightly. The rise is not sufficient to seriously alter the starch equivalent or protein equivalent. At the end of the period the material is still highly nutritious and of high digestibility but in the interval the total yield has markedly increased. This can be of the order of 30% more protein. Thus if crude protein percentage were the sole concern then utilisation could not be at too young a stage but if total yield is the concern, consistent with high digestibility, then the extra advantage that accrues in those three weeks in spring is considerable.

From the point of view of cost Hamilton (1955) gives a good estimate of production cost on the basis of nutritive value. He was concerned with the comparative costs of different types of animal fodder and he used the price per ton of starch equivalent as his basis. Any figure of this sort expressed in pounds or shillings tendsto be of value only for a short period owing to the constant change in costs. However, the ratio of costs under different systems of production are worth noting:

| | Av. yield in Tons/acre | Cost of S.E. in £s/ton |
|---|---|---|
| Grazing - effective production | - | 11 |
| Early bite " " | - | 14 |
| Grass silage | 5.2 | 17 |
| Kale grazed | 14.0 | 17 |
| " cut | 20.0 | 18 |
| Hay | 1.7 | 20 |
| Oats ($\frac{1}{2}$ straw fed) | 1.2 | 28 |
| Fodder beet roots | 12.0 | 33 |
| Tillage silage | 6.0 | 34 |
| Dried grass | 1.6 | 40 |
| Mangolds | 25.0 | 40 |
| Dairy cake £35/ton @ 65% S.E. | - | 54 |

By this the cost of early-bite S.E. is shown to be less than most other available fodders. It also stresses the saving that would occur in the cost of animal production if the feeding of purchased cake and conserved foods could be discontinued earlier in spring and more plentiful "early bite" grazing substituted.

## IX. ANIMAL DISEASES ASSOCIATED WITH GRASSLAND

An aspect of grassland production which has not so far been touched upon is its influence upon animal health. As grass is the major food of ruminant stock its quality greatly affects their nutrition. There are many instances where contamination of grassland by disease organisms can cause the spread of infection. Tuberculosis, Johne's disease, Anthrax, Brucella abortus, and foot and mouth disease are a few of the diseases that can remain infective for varying lengths of time on grassland. Eggs of internal parasites like roundworm and husk can also be transmitted on grassland but these ailments are matters of hygiene and pasture management. At worst they can be controlled by rotational cropping. They are not true nutritional illnesses.

In the past nutritional diseases of importance comprised conditions like rickets and around 1930 papers by people like Elliot (1928) typified this sort of study. In recent times importance has centred on the imbalance of trace elements and physiological disturbances like hypomagnesaemia.

The study of trace elements has been possible by refined methods of measuring the minute quantities of these elements in soil and herbage. This has mostly been done by the development of spectrographic analyses. Copper and cobalt if deficient in herbage are now known to be the cause of "pine" and "swayback" diseases. Copper deficiency usually occurs on peat land or where excess of lead or zinc inhibit its absorption by the animal. Both conditions can be prevented or cured by feeding appropriate mineral supplements. This discovery greatly increased the value of large areas in this country where these diseases had caused serious losses.

In other areas soils excessively rich in molybdenum produced a condition known as "teart" which causes economic loss in grazing stock unless treated with copper sulphate. Pastures on such soils rich in clover give the most serious symptoms.

Two diseases caused by organic substances in the plants of grazing pastures will serve to exemplify a further type of nutritional illness. The first is "sweet clover sickness" caused by the haemorrhagic effect of dicoumarin present in Melilotus alba. This is very rare in Great Britain as sweet clover is only grown in the south of England but is common elsewhere. The second is ragworth poisoning, which is more often heard of in horses than other stock. In this case the symptoms are a slowly progressive jaundice usually resulting in death unless diagnosed and treated. By earing ragworth the animal looses the ability to utilise vitamin B and this deficiency causes the clinical symptoms.

A disease concerned with grassland which is receiving considerable attention at present is "grass tetany" or "staggers". The reason is that its economic importance has increased greatly in recent years. Some farms which previously had no history of the disease have tended to have an increasing number of cases while others which in the past had only a few are now experiencing it with increasing frequency and in increasing severity. Due to the suddennness of onset and the high proportion of fatalities which can result if treatment is not quickly forthcoming investigation of the disease is very important. It is caused by hypomagnesaemia or lack of magnesium in the blood serum.

The condition is associated with low magnesium intake in the diet and is particularly prevalent in early spring. The use of fertilisers like sulphate of ammonia is also a contributory cause by increasing the leaching of basic elements such as magnesium from the soil. This in time reduces the level of magensium available to plants and hence the quantity in the herbage. In addition, the use of pure forms of calcium carbonate for liming in past years has not replaced losses in the soil content of magnesium. The condition is not easy to produce in animals experimentally but Bartlett (1957) was able to do so by making a sudden change of diet in spring. He found that there was about a week of time-lag between the change in diet and the onset of symptoms and during this time the blood magensium level dropped from as high as 2 mgms. per 100 mls. to as low as .5 mgms per 100 mls. The variations in this were greater between animals than between breeds. No difference was found between the effects of grazing, and cutting and carting the herbage to the animals. There was a close correlation between low serum magnesium and high serum nitrogen. It is thought that this is caused by a high level of ammonia production in the gut. This is its turn may be caused by the present of large quantities of amino-acids and partly synthesised proteins in very young spring herbage. At present the recommendations for prevention are to supply magensium carbonate as a mineral supplement for though cattle have large skeletal reserves of magnesium these cannot be mobilised quickly.

Another grassland deficiency that affects livestock in spring is caused by lack of sulphur. This is not experienced in Great Britain but in parts of Australia where soils are low in sulphur content. The rate of plant uptake of sulphur from such soils does not keep pace with the rush of spring growth. Sheep grazing such pasture suffer a temporary lack of sulphur in their diet which is reflected in their wool growth at that period. The wool fibres become very brittle and break causing loss in quality and hence reduced value.

For many years the illness known as bloat has caused a steady loss among grazing animals. As the condition is common when the herbage contains a large proportion of soft wet material like clover, prevention is often achieved by feeding extra roughages. However, the physical condition of the rumen contents does not explain all cases of bloat. Muir (1945) suggested that it might be caused by a hypersensitivity to some factor in the rumen flora or in the sward which could produce clinical symptoms with certain soil or temperature or other weather conditions. Shanks (1946) suggested that protein in the animal's blood could be the cause as histomine substances can produce tympanic reactions.

More recently cases of bloat have been found to be associated with the formation of a stable foam in the rumen. This foam inhibits the normal release of fermentation gases from the rumen and tympany soon results. This causes pressure on the heart, constriction of the lung cavity and asphyxia resulting in death in serious cases if treatment is not given promptly. Ferguson (1955) found that a lucerne extract which contained saponin-like substances produced these symptoms artificially. Normal saponins do not do this but foam-breaking compounds give quick relief to affected animals.

This quick outline of some of the diseases connected with grassland serves to show the main types of illness. The purely nutritional types affect the animal directly as a deficiency or an excess or indirectly by causing symptoms not immediately associated with died. The latter are by far the most difficult cases to solve. As some of the foregoing instances show several of them are promoted by the seasonal variation that occurs in spring in the composition of the grass. All ailments connected with grassland do not concern spring grass production but it is as well to remember that the very best grass even in spring is only as good as it is valuable to livestock. For this reason this section was included as an aspect worthy of consideration.

## SECTION II

## OUTLINE OF EXPERIMENTAL WORK

The study of factors affecting early spring growth in grassland was conducted by means of a series of trials and experiments dealing with as many relevant factors and their interaction as possible.

The work was spread over three years from October, 1956 to October, 1959. In actual fact a pilot experiment had already been laid down in May and another series surveyed and drawn up in June, 1956. This was a distinct advantage since a large number of results were obtained by May, 1957. It was possible in this way to get a pointer towards further investigations at an early stage in this work. Also, it provided not merely three seasons in which to carry out the work but three seasons in each of which a worthwhile volume of results could be obtained.

In all, some eighteen distinct investigations were conducted over the three years. Although each set out to discover the answer to a particular problem the answers were all closely related to the one main problem of how to grow grass earlier in spring. In these trials speed of working was essential because of the large volume of material to be handled in the comparatively short period of early spring. The analysis of results obtained in April also had to be done rapidly in order to incorporate any findings into the design of the following season's trials which were sown out in early May.

The first season's results indicated the most promising topics and the most fruitful lines of approach. The second season's findings clarified the main issues and directed the third season's efforts towards those things needing still further study and to certain details and minor issues linking the previous work together.

Looking back the issues now seem much more clear-cut than at any time since the beginning. At that point there was a definite hazyness about the problems and a feeling of groping for ways of tackling them. There is now a feeling of close-knit compactness about the work involved, with each result obtained, playing some part in the painting of the final picture. Nevertheless that picture is not final. All the problems are not solved. All the facts are not known and it is only with the greatest difficulty and reluctance that this research project is being broken off in order to compile the results obtained into thesis form. There are at least as many problems still needing a solution as at the beginning but they are new ones that have arisen out of the present work. It gives some satisfaction to think that in this way knowledge has been increased if only by a little.

For convenience a general outline of the experimental work is given together with a description of the techniques involved in obtaining the results. Thus, when the individual trials are discussed it will save repetition if only variations in technique need to be mentioned.

In the first season the main trials were directed towards estimating species' potentiality for early spring growth and their response to spring nitrogen, the effects of different length of winter rest on a sward's spring yield and the effect of winter defoliation on different species. By the second year this had developed greatly so that the species' potentiality trial now concerned firstly, a study of the rate of growth of different species and strains in their first four weeks of early spring growth. Secondly, the regrowth ability of these grasses after first defoliation in that early spring period. The effectiveness of nitrogenous fertiliser had expanded to cover both spring and autumn applications and their results as shown by spring yield. Also, the responsiveness of selected grasses to different quantities of spring nitrogen was studied. Winter resting and defoliation was taken back a stage to autumn-resting and its effect measured on mixed sward and on a pure single-species sward with and without the interaction of spring nitrogen. By the third year this had ramified further so that the species' potentiality trial now concerned responsiveness to different quantities of nitrogenous fertiliser. A complete trial was devoted to the study of all the available strains of one species which had shown special potentiality in earlier years. The trials with varying levels of autumn and spring nitrogen were repeated in refined form. The autumn resting trials were expanded to study the interaction of degrees of autumn rest and the autumn application of nitrogenous fertiliser on mixed sward and the interaction of different lengths of autumn rest and different amounts of autumn fertiliser on spring yield of a pure single species sward. How meaningful these trials are can only be seen after a close examination of their results but this resumé shows how the investigations developed along various lines and finally how the relationship between these major lines was co-ordinated.

Investigation of the problems ennumerated above was conducted under natural climatic conditions out of doors in one or other of two forms. Some of the trials were carried out using broadcast swards while for the rest grasses grown in drills were used. The former method was suited to those trials where a large area-plot was advantageous or where conditions approaching those of a farm pasture was desired. The drill method was particularly useful for measuring fine differences between species and strains. Much greater control of plants in drills is possible than when they are in a sward. Weed competition can be largely eliminated in drills and species or strain purity can be guaranteed in the harvested material. It does however, involve much more physical labour and far greater care and precision to conduct a whole series of drilled-plot trials than broadcast ones.

Defoliation treatments and harvesting of the broadcast plots was carried out using an Allen autoscythe with a special low-set cutter-bar to obtain close mowing. This cutter-bar left no more than between half and three quarters of an inch of stubble. For one series of broadcast trials harvesting was done by sampling the plots using a frame that was thrown to select the areas at random and then cutting the enclosed herbage with garden shears. In the second and third years this was speeded-up by using a modified Tarpen hedge-trimmer to do the actual cutting. On the drilled plots defoliation and harvesting was at all times done by hand using garden shears. This achieved accuracy by ensuring a uniform height of cutting but in the second and third years there was a total of almost 2500 yards of drills so that every cut required between a mile and a quarter and a mile and a half of painstaking shear work. Stubble in such cases was non-existent as cutting was to soil level. In this way subsequent cuts measured growth in the interval with no risk of the carry-over of material produced previously. The grass plants undoubtedly suffered a shock from this severe defoliation and in the December cutting some of them probably lost a lot of their stored food-reserves but this treatment was at least uniform and could also be consistent from one year to the next.

In farm practice the process of grazing-off excess autumn herbage in mid-winter would not be so severe as this even if sheep were employed.

This is no disadvantage because rigorous trial conditions reduce the risk of subsequent disappointment when any findings are applied to normal farm conditions.

Herbage from the broadcast plots harvested with the Allen-cutter was raked together, weighed fresh in the field and samples were drawn there for estimation of the dry matter content in the laboratory. In all other cases the total material harvested was collected by hand into rubber-lined bags, to avoid evaporation losses and each subplot weighed separately in the laboratory. Collecting by hand minimised the contamination of the herbage with soil-dirt which would have upset the yield weighings. Fresh weight was recorded to the nearest gram or nearest 10 gramms depending on the trial. Dried material was weighed to the nearest 1 gram. Dry matter estimations were conducted using 200 gram samples of fresh material placed in tins in thermostatically controlled ovens. The ovens were electrically heated, set to 100$^{\circ}$C $\pm$ .5$^{\circ}$ C with fan circulated air to ensure uniformity of temperature and took twelve hours to completely dry the samples. All results and calculations are on the basis of total dry matter yields, obtained as the product of total fresh weight and percentage dry matter.

When plots were being sown out the weight of seed used was calculated from recognised acre-scale pure-seeding rates. Seed for each subplot or drill was weighed out separately and packeted ready for sowing. The accepted pure-seeding rates take into account the size of individual seeds and the average establishment ability of each species. The aim was to ensure a strong establishment of grass seedlings and a similar plant density in each drill. Extreme measures were not adopted to ensure absolutely identical populations otherwise the main work would have been sidetracked onto the problems of seed-vigour and seedling viability. When sown alone ryegrasses are normally seeded at 25lb. per acre, by calculation this meant that 7 grams of seed were required per drill of 48 feet. Cocksfoot was sown at 5.5 grams and fescues at 6.5 grams for a similar drill length. These seed-rates were adhered to for all drilled trials. Weighing was done on an Avery automatic weighing machine with a plus and minus weight scale which ensured great accuracy yet was quick to use.

When broadcast plots were sown the subplots were marked out with string stretched from marking posts on the boundary of the trial area. The levelling of all plots was done with an iron-rake to ensure a very even surface and a fine tilth. This was very necessary with the drilled trials. Broadcasting of seed was done by hand followed by light harrowing and rolling. This proved to be very satisfactory in all cases. Drilled trials were laid out by carefully measuring the distances between drills and then drawing out the furrows with a garden-hoe or a furrow-marker. The depth was about one inch and the drills were purposely kept narrow for weed-control and subsequent foliage cutting. The actual sowing was done from the packet by hand. To ensure an even thickness of seeding requires skill by this method but the results were entirely satisfactory. It was essential that all seeding was done in windless conditions. Drills were covered over using a garden-rake. Weeds were dealt with by the frequent and regular use of a hand-hoe between the drills. Weeding was necessary from the time the seedling grasses appeared until late summer when their foliage over-shadowed the ground between the drills. Annual weeds that appeared within the drills had to be removed by hand-picking which was very slow.

Cutting might have served as an alternative method but it was desired to encourage the maximum vigour in the grass plants and for this reason no check, such as defoliation would cause, was permissible.

At an early stage it became important to decide what "spring growth" meant. In particular, when spring growth begins and winter ends. Something clear cut was desirable yet not so rigid that it would not accommodate climatic or other variations between one year and the next. After considering the physiological and climatic implications it was decided to consider the shortest day as the dividing mark between autumn and spring. Any growth occurring after this date was felt to constitute spring material. It may seem illogical to have no true winter but practical necessity required the removal of herbage produced at the end of one season before the commencement of the next. In any case there is no absolutely static period between the seasons when no growth occurs. Over-wintered herbage was not wanted in trials designed to measure spring growth so it had to be removed. Plant growth is at its lowest ebb in December and this demarkation was felt to be as sound as any other. As it was clearly impossible to defoliate every trial on precisely the shortest day the fact that so little growth occurs in December made it possible to spread the work over the whole month. Weather is not good then and the length of daylight limits the amount of outdoor work that is possible in any one day. If defoliation is done in November regrowth occurs before the shortest day while if left until January the risk of snow and hard frost stopping work entirely is too great. By choosing this definition of spring growth both the requirements of precision and flexibility were fulfilled.

From results obtained elsewhere and already reviewed in the literature it has been shown that phosphatic and potash fertilisers produce no great response in terms of early yield from grass. For this reason they were not employed in any of these trials. Steps were taken to ensure that neither potash nor phosphate was a limiting factor to growth in any trial. Likewise soil pH was maintained near neutrality. To do this each trial area underwent soil-analysis and every winter these basic fertilisers were applied to each plot requiring them.

Meticulous care was taken to ensure that no confusion of individual results occurred either in the field or during laboratory work. For this purpose every sample that was cut had an identification label for its bag. This label remained with that sample until all the laboratory weighings, samplings, drying and reweighings were complete. All results were recorded against the label number so that no confusion occurred. A separate key was maintained for each trial and the identification of subplot treatments or grass strains only took place as the statistical analysis of results was done. This proved a very satisfactory form of record keeping for this type of trial. Each year's experimental work was written up shortly after its conclusion so that minor factors and any events of importance were fresh in mind when a particular series of results was reviewed and discussed.

All calculations and statistical computation were carried out using a Friden electric calculator. This greatly facilitated and speeded this work particularly the statistical part. Permission to use this machine was greatly appreciated and thanks are hereby accorded for this facility.

Among the other records kept were those concerning the weather each spring. In particular temperature was important. The actual weekly averages that are set out were those recorded by the meteorological station at Bush which is situated a few hundred yards from the majority of the trial plots.

Photographic records were kept of certain aspects of the experimental work and of the equipment used. These are reproduced at relative points in the text.

## STRAIN POTENTIALITY TRIAL 1957

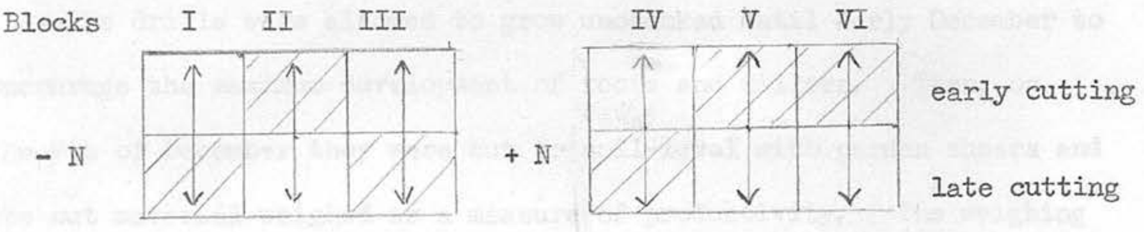
### Introduction

The first trial actually laid down was commenced in the end of May 1956. It was concerned with the potentiality of twelve selected strains of grass for early spring growth. The twelve species and strains employed were grasses normally considered to be early growing. The whole trial was intended as a pilot experiment which would indicate those grasses upon which further trials should be conducted.

### Layout

The twelve grasses were laid out at random in two plots each measuring 16 yards square situated side by side in Bush House drive. This meant that the total area covered approximately one-tenth of an acre. Three replicates were established in each of these plots. The six blocks were split crosswise so that one-half of each block was harvested at a very early date in Spring and the other about a fortnight later. The allocation of late or early harvesting was made at random within each block. It was desired to include some measure of the effect of a spring nitrogen fertiliser when superimposed on the trial. As the trial was a small one and as space was very limited this could not be incorporated into a statistical layout. Also the necessary space for discards between treatments was not available in the blocks. After some lengthy discussions it was decided that as this was a pilot experiment the purpose could be fulfilled by allocating the nitrogenous fertiliser to one or other of the two large plots. This meant in effect that three replicates would receive nitrogen en masse and three would not. To conduct a full statistical analysis afterwards would be impossible but the broad trends would be visible. This plan was adopted and gave a general guide to the responsiveness of the different grasses as well as experience in handling the experimental material, necessary for later trials.

The final layout is shown by the sketch plan -




12 drills each running as indicated across each block

Materials and Method

The twelve grasses selected for this potentiality trial were:-

| | |
|---|---|
| Danish Italian ryegrass | S 170 tall fescue |
| S 22 Italian ryegrass | Rhenish tall fescue |
| H I ryegrass | McGill & Smith's early fescue |
| N.Z. perennial ryegrass | S 215 meadow fescue |
| S 24 perennial ryegrass | Danish cocksfoot |
| Ayrshire perennial ryegrass | Meadow foxtail |

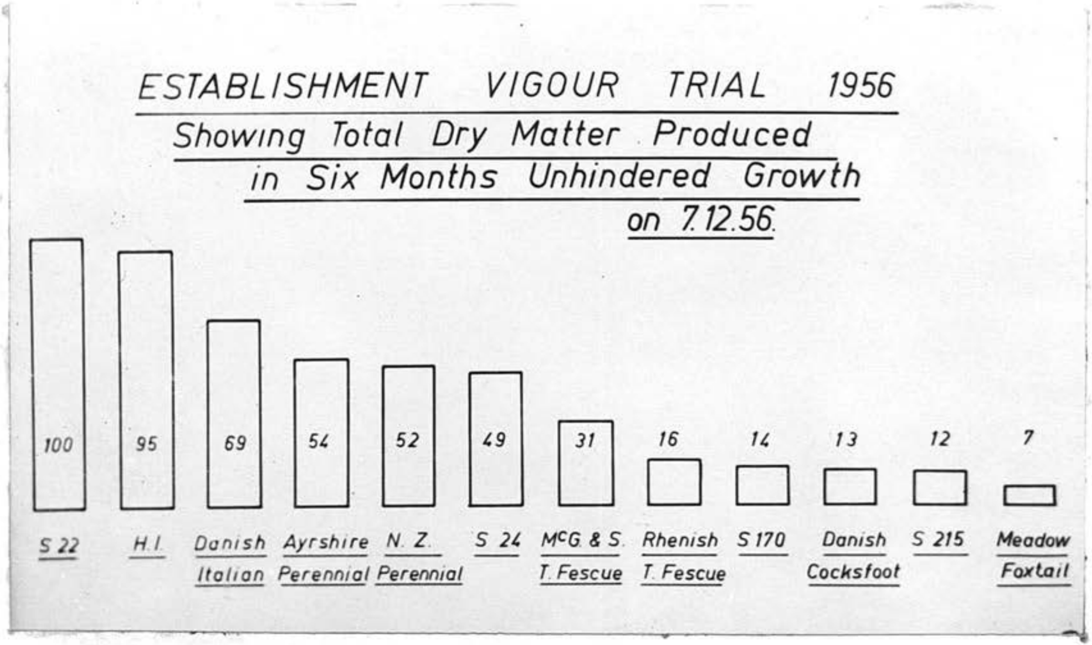
The ground occupied by the trial had been fallowed in the summer prior to 1956. In early May it had been rotovated and in late May it was marked out, firmed by treading and on June 6th was sown out in drills. The seed rates adopted were based on the pure seeding rate per acre for the different species already mentioned.

Germination was rapid and satisfyingly even along the drills. This reassured the critics that the method of hand sowing was accurate. Only meadow foxtail was slow to appear. During the summer weeds were kept in check by several hand-hoeings.

In November a soil analysis was conducted and in late December on the basis of this 3 cwts. per acre of sulphate of potash and 5 cwts. per acre of 21% Superphosphate was applied to improve fertility.

The drills were allowed to grow unchecked until early December to encourage the maximum development of roots and tillers. Then, on the 7th of December they were cut to soil-level with garden shears and the cut material weighed as a measure of productivity. The weighing of the herbage was done separately for each drill from three of the replicate blocks and on the basis of dry matter samples which were taken total dry matter yields were calculated. These figures gave an indication of the establishment vigour of the different grasses after six months growth. They were analysed in a simple statistical analysis which showed significant differences in average yields between the grasses.

On March 5th the area scheduled to receive spring nitrogen had an application of 2 cwts. per acre of nitro-chalk. The first cutting was carried out on March 27th and the second cutting three weeks later on April 19th. The fresh material was weighed to the nearest 10 grams.


ESTABLISHMENT VIGOUR TRIAL 1956
Showing Total Dry Matter Produced
in Six Months Unhindered Growth
on 7.12.56.
100
95
69
54
52
49
31
16
14
13
12
7
S 22
H.I.
Danish Italian
Ayrshire Perennial
N. Z. Perennial
S 24
McG. & S. T. Fescue
Rhenish T. Fescue
S 170
Danish Cocksfoot
S 215
Meadow Foxtail

and the dried material to the nearest 1 gram. The dry matter estimations were done separately for each drill.

Results and Discussion

In the establishment part of this trial, the results of which are shown by histograms, the ryegrasses clearly have the greatest vigour. The histograms show the relative yields of dry matter expressed as a percentage of the highest individual yield which was from S 22. The ryegrasses themselves fall into two groups namely the Italian type comprising S 22, H.I. and Danish, with the highest yields and the perennials somewhat lower.

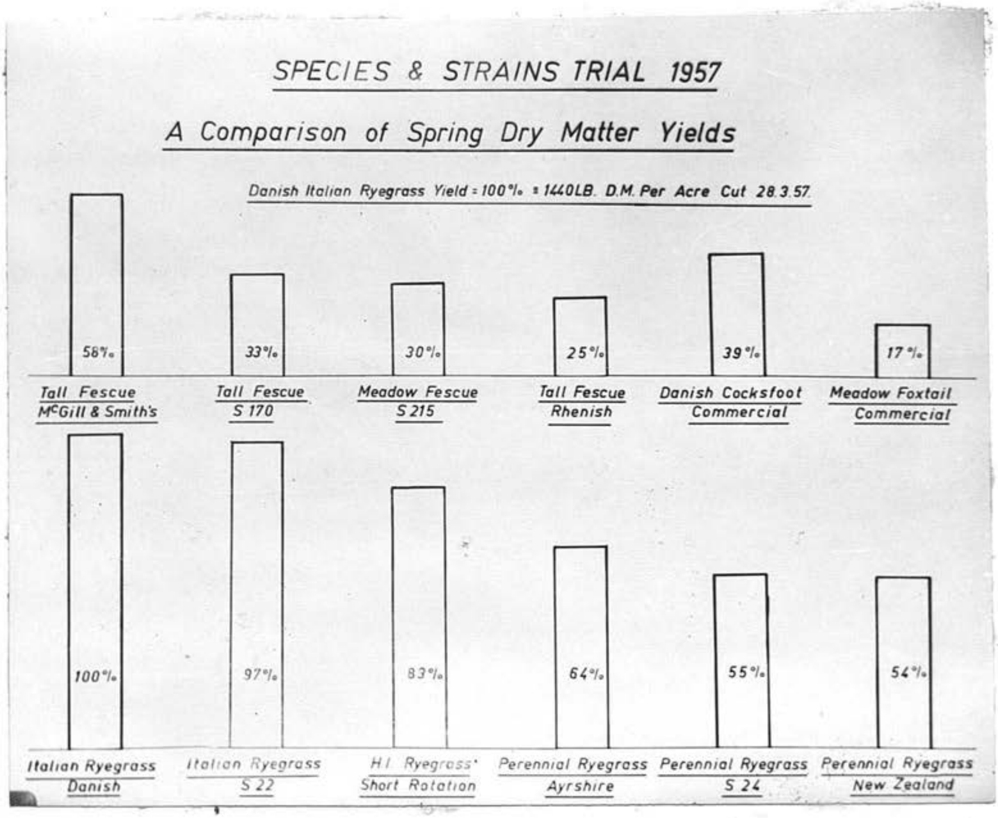
The mean yields are given below so that the actual quantitative power of each grass may be seen.

| | Mean Yield in gms. per 15 yards of drill | % |
|---|---|---|
| S 22 | 1417 | 100 |
| H I | 1346 | 95 |
| Dan. I.R.G. | 986 | 69 |
| Ayrshire | 758 | 54 |
| N.Z. Perennial | 733 | 52 |
| S 24 | 685 | 49 |
| McG. & S. | 446 | 31 |
| Rhenish | 234 | 16 |
| S 170 | 204 | 14 |
| Dan. Cocksfoot | 181 | 13 |
| S 215 | 168 | 12 |
| M. Fox. | 101 | 7 |

The significant difference at the $P = .05$ was 190 with S.E.= $\pm$ 64.9.

The other six grasses, which are all truly perennial show up very poorly in comparison with the ryegrasses due to their slow establishment ability. This picture is roughly the same as that provided by the spring yields of each species which are shown in the second histogram. The mean yields are also shown in tabular form but it should be remembered that these are average yields for each grass for all treatments. The same means are expressed as yield in pounds per acre. Little importance should be attached to these last figures because it is a computed figure for a large area based upon small samples and taken from drills. While the results are accurate when used as a relationship between grasses within the trial the errors inherent in translating to absolute yields are very great. Also, such yields only represent productivity at a particular point of time for one particular season. The only reason for including them is that some people are accustomed to think in pounds per acre as a unit of yield.

(See Table overleaf)


SPECIES & STRAINS TRIAL 1957
A Comparison of Spring Dry Matter Yields
Danish Italian Ryegrass Yield = 100% = 1440LB. D.M. Per Acre Cut 28.3.57.
58%
33%
30%
25%
39%
17%
Tall Fescue McGill & Smith's
Tall Fescue S 170
Meadow Fescue S 215
Tall Fescue Rhenish
Danish Cocksfoot Commercial
Meadow Foxtail Commercial
100%
97%
83%
64%
55%
54%
Italian Ryegrass Danish
Italian Ryegrass S 22
H.I. Ryegrass Short Rotation
Perennial Ryegrass Ayrshire
Perennial Ryegrass S 24
Perennial Ryegrass New Zealand

| | Mean yield in gms. per 7 yd. drill | % | Mean yield as lb. per acre |
|---|---|---|---|
| Danish Italian | 453 | 100 | 1437 |
| S 22 | 438 | 97 | 1389 |
| H I | 377 | 83 | 1197 |
| Ayrshire perennial | 291 | 64 | 921 |
| McG. & S. Fescue | 263 | 58 | 789 |
| S 24 | 251 | 55 | 753 |
| N.Z. perennial | 246 | 54 | 780 |
| Danish Cocksfoot | 177 | 39 | 561 |
| S 170 | 149 | 33 | 471 |
| S 215 | 138 | 30 | 438 |
| Tall Fescue | 114 | 25 | 363 |
| Meadow Foxtail | 76 | 17 | 240 |

The significant difference at P = .05 was 42 grams and the S.E.=± 14.6

The chief groupings are similar to those in the establishment - vigour assessment which constitute ryegrasses versus the rest. The only intrusion is McGill and Smith's Early Fescue. Within these two main groups the order of productivity is not identical to that in the establishment trial. Most noteworthy of all Danish Italian moved from third place to first by outyielding S 22. The difference in their spring yields is not significant statistically. The interesting thing is that Danish was able to improve its position to such an extent between December and March that it overhauled the lead possessed by S 22. H.I. also in the first three places in December remains there with 83% of the Danish yield. While this was considerably higher than the perennial ryegrass group it was significantly lower than the Danish and S 22 yields.

Of the perennial ryegrasses little need be said except to note that while their range of differences was 5% in December by March it had increased to 10% due to the increase in vigour of Ayrshire perennial. McGill and Smith's early fescue was notably earlier than any other fescue by 25%. This result gave 'early fescue' a status of some importance because it was in a class by itself compared to the other fescues. It was not until much later that the cause of this high yield was discovered. The drills of this grass proved to contain a high proportion of Italian ryegrass and was the only strain to show impurities of this sort. The presence of Italian ryegrass would have been noticed sooner in the second or third year of trials when more experience had been gained. In order not to upset the trial layout for the 1958 series these drills received the same treatment as the rest of the area and were allowed to grow until 1958. There were thus no blank areas in the 1958 trial though the early fescue was not part of the trial in that spring. It again yielded well in 1958 but the Italian ryegrass had by then mostly died. Its place however was taken by cocksfoot. The original samples of seed which had been retained for just such a contingency and the supplier's analysis were investigated. They showed 4% of 'other useful seeds'were present. These proved to be mostly Italian ryegrass and some cocksfoot seeds. As cocksfoot seed is much smaller and lighter per seed than fescue this represented a large number of extra plants in the established drills. This provides an example of the errors that can be caused by impure samples of seed. The mystery was however solved.

Danish cocksfoot was another grass which showed strong growth ability in the period between December and March. In that time it improved from tenth to eighth place by surpassing S 170 and Rhenish tall fescue in yield. Nevertheless both tall fescue and cocksfoot gave disappointing yields in view of their esteem as early grasses. Meadow foxtail proved very disappointing being consistently the lowest yielding grass. At no time did it exhibit the vigour which is necessary in a grass for it to have the potentiality of high yield in spring. Its claim to earliness appeared to rest on its ability to produce flowerheads sooner than any other grass in the trial. By the second cut in mid-April a large number of these had appeared. It was also noticeable that it did this without ever passing through the stage of producing a vigorous amount of vegetative growth and leafage. It was the only grass to show the presence of weeds due to its poor vigour. Agrostis and red fescue were present in the foxtail drills but no attempt was made to remove them at this stage due to the small bulk of their yield and the unsatisfactory performance of their host grass. For these reasons meadow foxtail was discarded from all further trials.

It has been pointed out that it is not possible to isolate the nitrogen effect in the analysis. Nevertheless by observation alone the effect of the nitro-chalk was evident and the extra yield it produced was considerable. It was possible to analyse the effect of nitrogen fertiliser in the interaction with strain productivity and with date of harvesting. The former of these interactions is of some importance and is shown in the following table.

(See Table overleaf)

| Strain | Mean Yield Difference (between + N and - N) | Mean Yield expressed as percentage of highest mean |
|---|---|---|
| S 22 | 264 | 100% |
| H I | 240 | 91% |
| Danish Italian | 209 | 79 |
| Ayrshire perennial | 139 | 52 |
| New Zealand perennial | 135 | 51 |
| McGill & Smith's Early Fescue | 128 | 48 |
| Danish cocksfoot | 92 | 34 |
| S 170 | 71 | 26 |
| Rhenish Tall Fescue | 68 | 26 |
| S 24 | 62 | 23 |
| Meadow Foxtail | 22 | 8 |
| S 215 | 21 | 8 |

Significant difference = 84 for P = .05

S.E. = ± 29.2

This shows the relative ability to utilise nitrogen. S 22 has a significantly higher yield than Danish Italian which is reduced to third place. This would indicate that S 22 and H I show to better advantage under high fertility than does commercial Danish Italian. One drill of Danish Italian with three other neighbouring grasses in one replicate appeared to be affected by a patch of low soil fertility. This caused a reduction in the mean yield of Danish Italian and as it occurred in a plot receiving nitrogen it caused a reduction in the difference between the mean yields for nitrogen and no nitrogen treatments. For this reason the importance of the change in relative placing should not be overstressed. The problem of assessing the relative ability to utilise high nitrogen fertility was pursued further by making it the subject of a separate trial for the following spring of 1958.

The effect of harvesting date on yield is shown in the following table.

| Treatment | Mean yield for all strains |
|---|---|
| early harvesting | 125 |
| late harvesting | 371 |

Significant difference = 15 for P = .05

S.E. = ± 5.1

This result indicates that the longer growing plants are left the greater the dry matter produced which is hardly surprising. It was interesting, however , to note that the degree of increase was threefold in the three weeks between the two cutting dates. This in its turn led to further investigation of the rate of dry matter production of different grasses in the following spring of 1958.

The interaction between date of harvesting and the effect of nitrogen fertiliser on yield is shown next.

| Treatment | Mean Difference in Yield between + nitrogen and - nitrogen |
|---|---|
| early harvesting | 54 |
| late harvesting | 188 |

Significant difference = 30 for P = .05

S.E. = ± 10.4

This demonstrated that nitrogen treated plots produced a greater increase in yield between the two cutting dates than untreated plots. This means in effect that all the applied nitrogen was not utilised by the date of the first cutting.

The results of the interaction between individual strain productivity and time of cutting is shown below.

| Strain | Mean Differences in Yield between cutting dates |
|---|---|
| Danish Italian | 416 |
| S 22 | 408 |
| H I | 359 |
| Ayrshire perennial | 291 |
| McGill and Smith's Early Fescue | 269 |
| S 24 | 253 |
| New Zealand perennial | 242 |
| Danish cocksfoot | 213 |
| S 215 | 155 |
| S 170 | 138 |
| Rhenish tall fescue | 119 |
| Meadow foxtail | 86 |

Significant difference = 36.3 for P = .05

S.E. = ± 12.8

Some strains produced a greater increase in their dry matter yield in the interval between the two cuts than did others. The relative positions of the three highest yielding grasses Danish Italian, S 22 and H.I. remained unchanged however.

By cutting the regrowth on the early harvested plots at the same date as the late harvesting cut a measure of recovery potential was obtained. This was capable of separate analysis and like the assessment of establishment vigour constitutes a minor trial within the main trial. The total yield of all nitrogen treated plots was approximately double that of untreated plots. The mean yields for individual strains were as shown below.

| Strain | Mean Yield of regrowth |
|---|---|
| Ayrshire perennial | 374 |
| Danish Italian | 316 |
| S 22 | 312 |
| S 24 | 299 |
| H I | 289 |
| New Zealand perennial | 275 |
| McGill and Smith early fescue | 215 |
| Danish cocksfoot | 204 |
| S 215 | 204 |
| S 170 | 145 |
| Meadow foxtail | 124 |
| Rhenish tall fescue | 103 |

Significant difference was 40 for P = .05

S.E. = ± 14.0

Ayrshire perennial gave a remarkable quantity of second growth surpassing that of the Italians. The clear distinction between Italian and perennial ryegrass results has disappeared and the yields of both are intermingled. The remainder show no outstanding performance. Meadow foxtail at last managed to outyield something else but not by much.

It was felt that the use of dry matter as the only means of assessing worth was perhaps inadequate. For this reason protein analyses were undertaken on fifty-one dry matter samples. Each of these represented the bulked material from three replicates of drills receiving identical treatment. Each strain was analysed separately. The analysis was by the standard Keldahl method of nitrogen estimation from which crude protein content was calculated. The effect of the different treatments on the protein content of individual strains is shown on the attached table.

No endeavour was made to conduct a statistical analysis of protein yields due to the enormous number of protein estimations it would have entailed. Bulked samples were felt to be adequate to give a clear indication of any trends.

The results obtained from the early harvest cut in the first week of April when no nitrogen fertiliser was used were taken as the basis for comparisons.

The grasses giving the lowest gross yields of dry matter had the highest crude protein percentages though their total yields of crude protein were not high. The highest total yields were given by

| Strain | Early Cut | | | | Late Cut | | | | Recut | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -N | | +N | | -N | | +N | | -N | | +N | |
| | % | CP lb/acre | % | CP lb/acre | % | CP lb/acre | % | CP lb/acre | % | CP lb/acre | % | CP lb/acre |
| S 215 | 24.1 | 46 | No further crude protein assessments were made due to the low total dry matter yield of these grasses. | | | | | | | | | |
| Rhenish tall fescue | 19.4 | 25 | | | | | | | | | | |
| McGill & Smith Early fescue | 18.4 | 60 | | | | | | | | | | |
| Meadow foxtail | 24.5 | 16 | | | | | | | | | | |
| S 24 | 21.2 | 70 | | | | | | | | | | |
| S 170 | 19.6 | 45 | 25.1 | 69 | 13.0 | 63 | 15.1 | 136 | 14.1 | 8 | 12.6 | 12 |
| Ayrshire perennial | 20.8 | 74 | 27.3 | 154 | 11.0 | 116 | 15.3 | 263 | 9.81 | 12 | 12.6 | 35 |
| Danish cocksfoot | 25.1 | 46 | 32.4 | 85 | 11.6 | 75 | 15.4 | 178 | 12.7 | 10 | 11.6 | 16 |
| New Zealand perennial | 21.8 | 59 | 26.1 | 136 | 11.8 | 101 | 13.6 | 200 | 10.9 | 10 | 10.3 | 20 |
| Danish Italian | 18.1 | 117 | 26.9 | 243 | 9.69 | 151 | 16.5 | 434 | 12.9 | 15 | 11.0 | 24 |
| S 22 | 18.6 | 98 | 29.2 | 278 | 11.8 | 167 | 15.4 | 409 | 12.3 | 13 | 12.8 | 28 |
| H. I. | 18.5 | 85 | 27.4 | 216 | 10.5 | 122 | 15.8 | 374 | 11.8 | 10 | 10.8 | 23 |

% content of crude protein in dry matter derived by standard nitrogen assessment.

the three Italian ryegrasses which had the lowest crude protein percentages.

The three Italians, two perennials and S 170 and Danish cocksfoot had protein assessments done for the entire trial series. From these it is easy to trace the trends as growth continued through April and the effect of cutting on subsequent protein yields. The effect of nitro-chalk in the first cut increased the protein contents of the non Italian group by amounts varying from 4% to 7%. In the Italian group the increase was from 9% to nearly 11% with S 22 giving 29.2% crude protein. This yield coupled with the high dry matter output of S 22 represented a total of 278 lb. of crude protein per acre. To obtain this in the end of March by any method is outstandingly good. The highest individual protein content was from Danish cocksfoot which had 32.4% crude protein. The later cut shows a general decline of some 10% for each treatment compared with the first cut. The nitrogen treated drills each yielded about 15% crude protein and those without nitrogen about 11%. By the time this cut was taken no great differences remained between the individual strains. In the recent trial those drills with no nitrogen show little difference compared with the late cut yields. Those drills which had received nitrogen then showed no effect of this in their protein contentswhich are fairly uniform at about 12%. Since these drills did give a greater dry matter yield in the regrowth cut their total protein output exceeded that of the no-nitrogen drills. The effect of the nitrogen application was obviously fading out by then but nevertheless it had promoted a very good total protein and dry matter output in the interval.

The general picture that this protein assessment gave was one of abundant protein in the early spring period. In most cases the crude protein percentage was so high that livestock would normally be unable to utilise it fully. The conclusion from this was that any worthwhile bulk of herbage that can be produced in early spring will be so rich in protein that there is little point in determining its percentage content in the dry matter. The real aim therefore is to produce the maximum quantity of dry matter. For this reason no further protein analyses were conducted, attention being focussed upon dry matter alone.

Conclusion

This series of experiments could have been presented as several separate trials but it was felt advisable to present them together, even though this made a bulky quantity of results. Looking back it was surprising that so much material could be derived from a single series of trials. The reason is probably that it was a pilot experiment and the differences that were sought were large ones and therefore fairly clear cut. Some of the reactions such as the fertiliser response had been anticipated but provided a useful basis for subsequent trials.

The most important single fact that emerged from this series was the supremacy of Italian ryegrass in the first harvest spring for the production of high quality dry matter at an early date.

# WINTER RESTING TRIAL 1957

## Introduction

In June 1956 it was decided to lay down a trial on an established ley-sward to determine the effects of autumn resting on the subsequent spring yield. Several sites were visited and one chosen as suitable for the work. Due to uncertainty about future ploughing policy this site had to be abandoned and another found. With the difficult hay-making weather in July of that year this second area was rendered very patchy by hay coils and so the trial was moved yet again, in August, to a third site. The trial was laid out, pretreatment cuttings begun and at last the trial was underway on a very suitable vigorous sward. After six weeks of autumn management cattle broke into the area and ruined many of the plots. Yet again a new site had to be found. This time is was in Lower Fulford field at Boghall where it was securely fenced but was not ready until late October. For this reason it was not possible to repeat the autumn resting treatments as growth had practically ceased by then. In view of this it was decided to initiate a winter resting programme and study the effects, if any, of different degrees of resting on spring yield. As rest is synonymous with freedom from defoliation the trial may be thought of as being similar to a study of the effect of grazing sheep on spring yield when they are allowed to graze a pasture late into the winter.

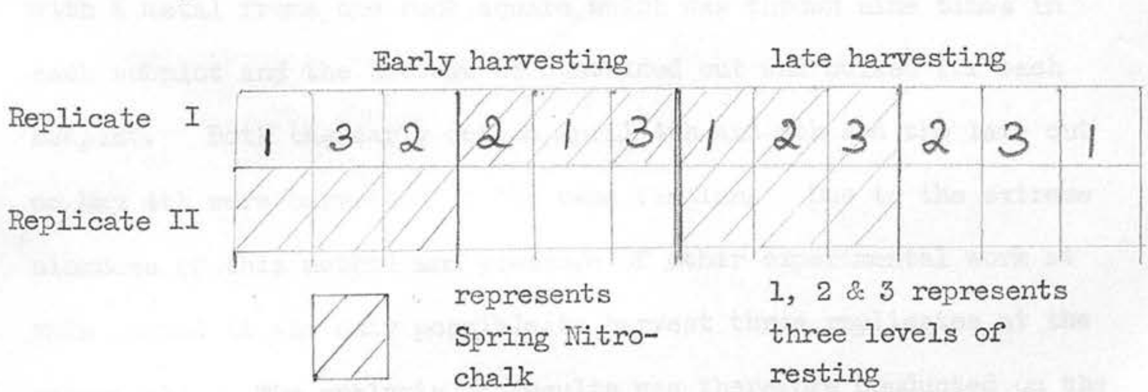
The sward was not ideal for early grass production since it had been sown six years previously in 1950. It contained a high proportion of perennial ryegrass, cocksfoot and timothy with some wild white clover in addition to red fescue and Agrostis. The useful species that remained were obviously represented by their more permanent strains which start growth late in spring.

The field had been grazed in the early part of the summer of 1956 and then cut for silage. It was in a vigorous and fresh condition when enclosed for the trial.

Materials and Method

The total area of the trial measured 36 yards by 32 yards and was divided into 4 replicates each containing two main plots. One of each main plot was allocated at random for early spring harvesting and one for late cutting approximately a fortnight after the first. These main plots were each divided to allow spring nitrogen fertilising to be carried out at random to half the plot. These divided plots were each divided further to allow three degrees of leniency of winter resting. The allocation of this rest treatment was at random within each three subplots. The total number of subplots was forty-eight and each measured 8 yards by 3 yards. This allowed for adequate discards and left a cutting area of 6 yards by 2 yards which is approximately 1/400th of an acre.

The layout for each replicate resembled the following plan:-



The actual layout was suggested by Dr. Lawley as being statistically suitable and proved very satsifactory. The resting process was preceded by cutting the herbage with the 'Allen-cutter'. The most lenient treatment was one cutting in the first week in December and then rested until the spring harvesting began. The second involved two cuttings - in the first week in December and the first week in January and then rested. The third involved cutting in December, January and the first week of February and resting thereafter. The title winter resting trial could easily have been winter defoliation trial as the one is the converse of the other in this trial.

A soil analysis was carried out in December 1956. The pH, $K_2O$ and $P_2O_5$ availability levels were found to be satisfactory so that no application of these basic fertilisers was necessary. On March 5th nitro-chalk at the rate of 2 cwts. per acre was applied to those plots due to receive spring nitrogen. This was weighed out separately for each subplot beforehand and applied very carefully by hand. In spite of the mild spring the response was slow. Other trials were cut as early as March 28th but by the first week of April there was insufficient growth to make cutting with the Allen-cutter possible. Resort had to be had to hand shears. This was done in conjunction with a metal frame one foot square which was thrown nine times in each subplot and the herbage it contained cut and bulked for each subplot. Both the early cut on April 4th and 5th and the late cut on May 4th were harvested in the same fashion. Due to the extreme slowness of this method and pressure of other experimental work at this period it was only possible to harvest three replicates at the second cut. The analysis of results was therefore conducted on the basis of three replicates.

Results and Discussion

The results show that date of cutting had a significant influence upon the quantity of material harvested. The mean dry matter yield at the first or early cut was 52 gm. compared with 176 gm. at the later cut which was a mean difference of 124. The degree of difference necessary to achieve significance was 96 for $P = .05$ S.E. = $\pm$ 15.8. In lb. per acre the yields were 554 lb. and 1876 lb. per acre respectively.

This result is not surprising since it shows that the longer one waits before cutting the greater is the yield.

The fertiliser nitrogen effect is shown below:

| Treatment | Mean Yield in gms. | Mean Difference in gms. | Mean Yield in lb. per acre |
|---|---|---|---|
| Nitro-chalk | 136 | 45 | 1450 |
| No Nitro-chalk | 91 | | 970 |
| when $P = .05$ | Significant difference | | 12 gm. or 128 lb. |

S.E. = $\pm$ 4.3

This shows that at 2 cwts. per acre nitro-chalk gives a significant increase in the spring yield of herbage.

The interaction between nitrogenous fertiliser and time of harvesting was also significant.

| Treatment | Mean difference between yield from fertiliser and no fertiliser | Mean difference between cutting dates |
|---|---|---|
| Late cutting | 66 | |
| | | 46 |
| Early cutting | 20 | |

Significant difference = 24 when P = .05 S.E. = ± 8.7

This interaction of fertiliser and time of cutting shows that the early cutting took place before the sward had time to fully utilise all the applied nitro-chalk. Thus by the second harvesting date there was better utilisation of nitrogen.

The effect of resting treatments:

| Treatment | Mean Yield in gms. | Mean Difference | | Mean Yield lb. per acre |
|---|---|---|---|---|
| Rested from December onwards | 126 | | | 1343 |
| | | 13 | | |
| Rested from January onwards | 113 | | 24 | 1205 |
| | | 11 | | |
| Rested from February onwards | 102 | | | 1087 |

Significant difference = 10 when P = .05

S.E. = ± 3.4

This result is very interesting since it shows that the more often a sward is defoliated even in mid-winter the more it is weakened and the less productive it is in the early part of the spring.

The effect of two defoliations is significantly greater than one. The effect of three defoliations is only just significantly greater than two defoliations but the trend is maintained nevertheless. The effect of three defoliations compared to one defoliation is clearly greater than any other.

Had the weather been colder these effects might not have been noticeable but as it was it was shown that in a mild winter defoliation does depress the spring yield. In farm practice the defoliation treatment would possibly have been more severe since the constant nibbling of sheep could cause more than a maximum of three defoliations as was employed here. This is due to their tendency to remove new growth constantly as it occurs. In this way the difference between resting from December and resting from February could have been greater.

# WINTER DEFOLIATION TRIAL 1957

## Introduction

This was a trial included in the 1957 series which utilised eight grasses that had been grown for a winter foggaging trial in 1956/57 by the Botany Department. The harvesting of the foggage had involved the removal of live and dead material in the middle of December, January and February. This harvesting constituted the defoliation pretreatment for the present trial. The regrowth that occured between the date of foggage cutting and the end of March indicated the recovery vigour of each strain for each defoliation date.

The previous trial detailed, which was done in Fulford field was directed towards measuring the effect on the spring dry matter yield of a sward when subjected to different severities of winter defoliation. Severity was constituted by the number of times defoliation took place. This present trial concerned the effect of the date of one defoliation upon eight distinct grasses grown separately in drills.

## Materials and Method

The eight grasses employed comprised two strains of each of the four species cocksfoot, timothy, meadow fescue, and tall fescue. The actual strains were S 143 and S 37 cocksfoot, S 48 and S 51 timothy S 53 and S 215 meadow fescue, and S 170 and Rhenish tall fescue.

The drills were sown in April 1956 each being 33 feet long and 18 inches apart. The weight of seed used was calculated from pure-seeding rates. Three drills of each grass were sown together to allow one for each winter cutting date. The strains were placed at random within each of the three replicates. Of the three drills of each grass the centre one was cut in mid December and the left and right hand drills in mid-January and mid-February respectively. Each replicate block had one yard separating it from the next. Discard drills were present at the edge of each block and one yard of drill at each end was discarded leaving 9 yards for harvesting. Cutting was carried out on March 28th using garden shears. Weighings were to the nearest 10 grams for fresh material and analysis was on the basis of calculated total dry matter yield.

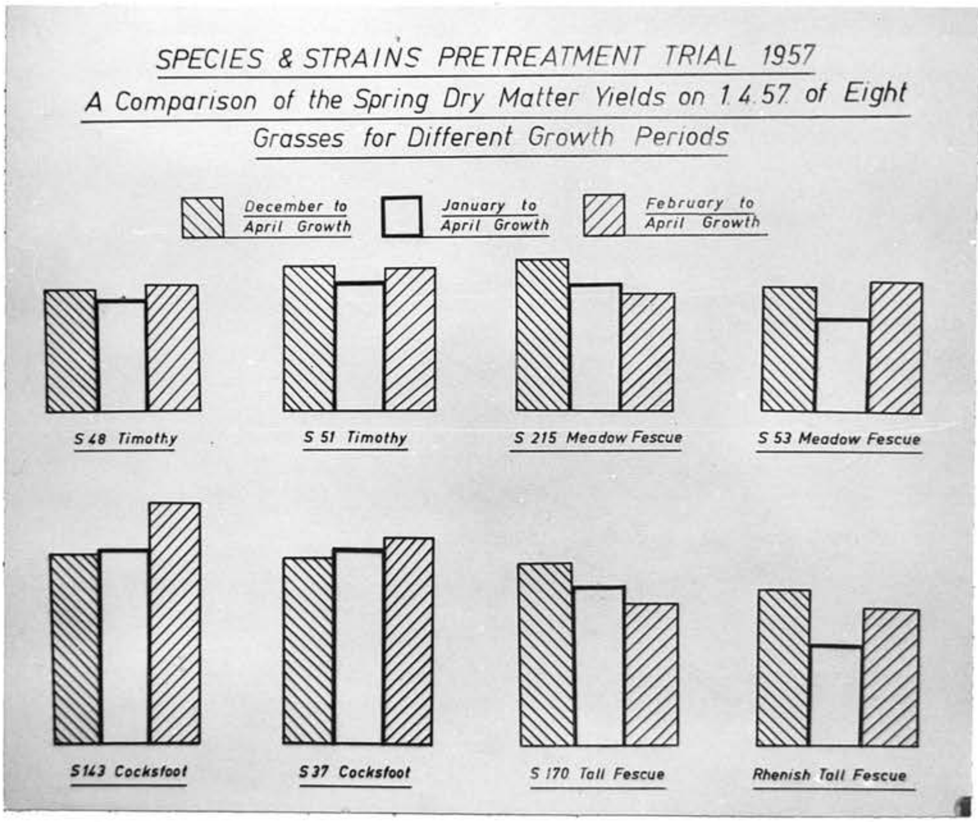
Results and Discussion

The effect of time of defoliation did have a significant effect upon yield of dry matter as the mean yields show

| Date of pretreatment Defoliation | Mean Yield in grams. | Mean Differences | |
|---|---|---|---|
| December | 387 | | |
| | | 46 | |
| January | 341 | | 5 |
| | | 41 | |
| February | 382 | | |

Significance requires a difference of 39 for P = .05. The SE = $\pm$ 13. The curious feature of this result is that February defoliation had on the whole a similar effect to December defoliation. The yield produced by all strains between mid February and the end of March was practically the same as that produced between mid December and the end of March. This could be comfortably dismissed as being due to lack of growth activity between December and February if it were not for the January to March yield being so much lower. The great trough in the pattern of yield which the January defoliation produced indicates that conditions at that time were very adverse to recovery. The period of mid-January to mid-February did mark the coldest part of the winter with the average mean temperature at approximately 35 $^{o}$F. From this one can only surmise that the December defoliation caused a check to the grass plants concerned which was prolonged by the subsequent cold weather in late January. The January defoliation on the other hand occurred at the worst time as the plants then possessed no herbage cover and had little chance to make any regrowth for a month, until the end of the cold spell. By that time the plants had used a large quantity of stored food reserves merely in maintenance while the other two had both foliage protection and means of food production for their maintenance requirements. The February defoliation was carried out on plants which had suffered none of these drawbacks. They had both protection for their basal tillers from the uncut herbage and adequate photosynthetic tissue to meet their food requirements. The check they suffered by defoliation was therefore no less than the other two but was of very short duration. It was therefore possible for the February defoliated plots to start from nil in mid February and yet equal the December to March yield six weeks later.

Significant differences were also obtained between the mean strain yields for each strain which are set out below.


SPECIES & STRAINS PRETREATMENT TRIAL 1957
A Comparison of the Spring Dry Matter Yields on 1.4.57 of Eight Grasses for Different Growth Periods
December to April Growth
January to April Growth
February to April Growth
S 48 Timothy
S 51 Timothy
S 215 Meadow Fescue
S 53 Meadow Fescue
S143 Cocksfoot
S 37 Cocksfoot
S 170 Tall Fescue
Rhenish Tall Fescue

| Strain | Mean Yield in gms. | Yield as % of the highest Mean | Yield in lb. per acre |
|---|---|---|---|
| S 143 | 518 | 100 | 1104 |
| S 37 | 484 | 93 | 1031 |
| S 48 | 296 | 57 | 631 |
| S 51 | 342 | 66 | 729 |
| S 53 | 282 | 54 | 601 |
| S 215 | 319 | 62 | 680 |
| S 170 | 396 | 76 | 844 |
| Rhenish | 320 | 62 | 682 |

Significant difference for gram means = 139 $P = .05$ $SE = \pm 45.7$

This shows that of the species investigated,the cocksfoots were decidedly the highest yielders and meadow fescues the poorest. The tall fescues and timothies occupied an intermediate position. The plot layout did not allow of the statistical analysis of the four species as units only as eight individual grasses. Nevertheless by expressing the mean yield of each strain as a percentage of the S 143 yield a good comparison of yielding power is obtained. It is for comparative purposes that these yield figures are of most value. If absolute yields are deduced from them then serious errors could arise. In drills, a strain such as S 143 spreads laterally and so the yield from a given length of drill is provided by a larger number of tillers than the same length of, for instance, tall fescue drill. In a closed sward this would not arise.

The yield for each strain is shown in the following histogram. Although there was no interaction between species and defoliation date the yield derived by each strain from each defoliation treatment is shown separately. From this it is clear that the overall reaction to date of defoliation namely low January regrowth is not shown by every strain. In fact no general pattern of reaction to defoliation pretreatment is visible.

The total area covered by each strain's histogram represents the total dry matter yielded by it in the end of March. From this one fact emerges clearly that the cocksfoots yield most under this treatment and S 143 most of all.

## SPECIES AND STRAINS GROWTH RATE TRIAL 1958

### Introduction

The results of the 1957 potentiality trial indicated the need to investigate several problems further. One of these concerned the different rate of growth of certain grasses in the very early spring period. As the purpose is to study spring growth a certain amount of time must be allowed for it to take place and so the idea of the early spring period is valid. The other trials have measured results at a particular point of time in spring or at two points but this is not sufficient to show the reaction of different grasses to conditions prior to those points of time or between them. The detailed study of this was therefore undertaken in the spring of 1958.

### Method and Materials

The two trial areas used in the pilot assessment of spring growth potential in 1957 were used for this trial. The grasses that had been established for the 1957 trial were maintained for use in the spring of 1958. This had the advantage that the perennial grasses such as tall fescue were well established and could compete on equal terms with shorter lived grasses. The drills occupied by meadow foxtail were dug with a spade and reseeded with Danish Italian ryegrass.

During the summer of 1957 free growth was encouraged but flowering heads were mown off to preserve vegetative vigour. By December 1957 the six replicates looked very even and in good condition for the spring trial.

On March 6th the whole trial area received 3 cwts. per acre of Nitro-chalk and the same of sulphate of potash and 21% super-phosphate. The customary method of weighing and applying fertiliser separately to each replicate was followed. Each replicate was then split crosswise into four sub-plots and a different harvesting date allocated at random to each of these. The four dates were at weekly intervals over the early spring period. With the late spring they in fact covered the period from April 22nd to May 13th. The first cutting on April 22nd took place little more than a week after growth commenced when very little foliage was present. The entire period thus covers the first four weeks of active growth. The results show the tremendous rush of growth in this period which must have been exceptionally rapid due to the late start.

The adverse winter weather had completely killed the H.I. and S 22 and most of the Danish Italian ryegrass by April. These were all in their second winter and in spite of the removal of flowerheads in the previous summer they behaved like biennials and so no results were available for them.

Within each subplot there was one drill of each grass. The length of drill harvested in each sample was precisely nine feet after removing discards. This was a small sample but with six replications the results gave accurate information.

Results and Discussion

A statistical analysis was conducted on the dry matter yields and the results are shown by tables. The individual results are more easily shown in histogram form in this trial than by numerical analysis alone and so both are used.

Effect of Grass Strain

| Grass | Mean Yield |
|---|---|
| Danish cocksfoot | 238 |
| S 215 | 158 |
| S 170 | 135 |
| Rhenish tall fescue | 108 |
| Ayrshire perennial ryegrass | 104 |
| S 24 | 99 |
| Danish Italian | 65 |
| New Zealand perennial ryegrass | 42 |

Significant difference = 18 for P = .05

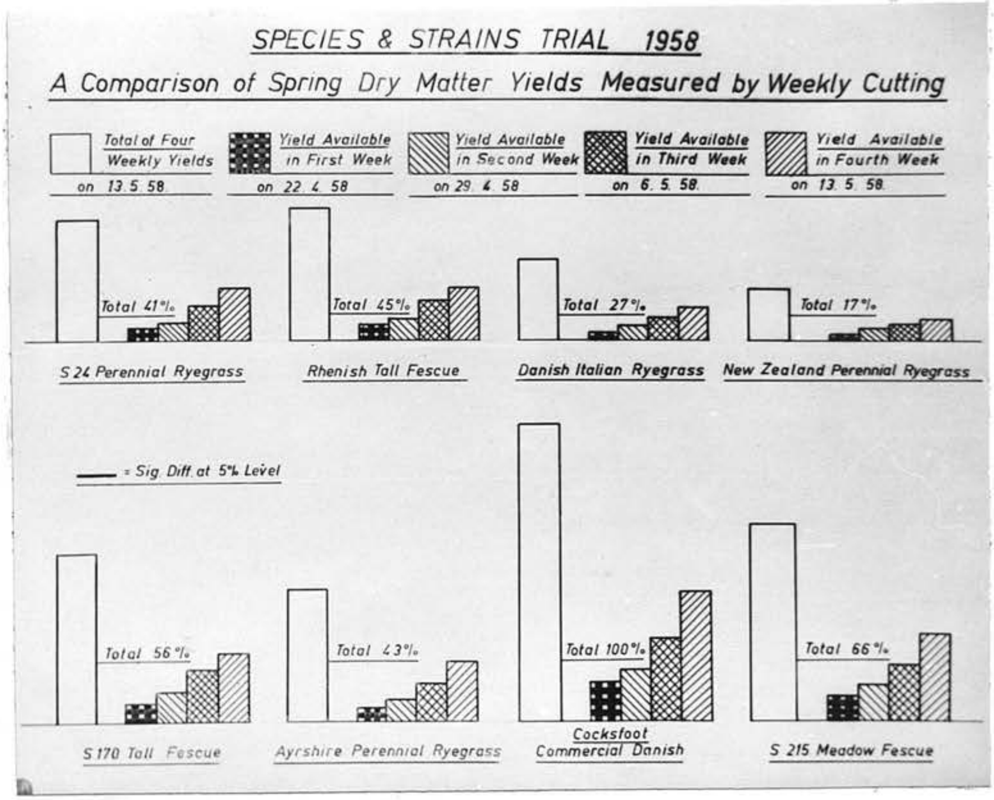
S.E. = ± 6.2

Effect of Spring Harvesting Date

| Harvesting date | Mean Yield |
|---|---|
| April 22nd | 53 |
| April 29th | 82 |
| May 6th | 136 |
| May 13th | 204 |

Significant difference = 9 for P = .05

S.E. = ± 3.1


SPECIES & STRAINS TRIAL 1958
A Comparison of Spring Dry Matter Yields Measured by Weekly Cutting
Total of Four Weekly Yields on 13.5.58
Yield Available in First Week on 22.4.58
Yield Available in Second Week on 29.4.58
Yield Available in Third Week on 6.5.58
Yield Available in Fourth Week on 13.5.58
Total 41%
S 24 Perennial Ryegrass
Total 45%
Rhenish Tall Fescue
Total 27%
Danish Italian Ryegrass
Total 17%
New Zealand Perennial Ryegrass
= Sig. Diff. at 5% Level
Total 56%
S 170 Tall Fescue
Total 43%
Ayrshire Perennial Ryegrass
Total 100%
Cocksfoot Commercial Danish
Total 66%
S 215 Meadow Fescue

Interaction between Harvesting Date and Grass strain

| Grass | 1st Cut Mean Yield | 2nd Cut Mean Yield | 3rd Cut Mean Yield | 4th Cut Mean Yield |
|---|---|---|---|---|
| Danish Cocksfoot | 116 | 162 | 262 | 415 |
| S 215 | 71 | 106 | 176 | 278 |
| S 170 | 64 | 93 | 160 | 222 |
| Rhenish tall fescue | 54 | 71 | 129 | 178 |
| Ayrshire perennial | 40 | 65 | 122 | 190 |
| S 24 | 41 | 66 | 114 | 173 |
| Danish Italian | 22 | 51 | 77 | 112 |
| N.Z. perennial | 14 | 38 | 49 | 67 |

Significant difference = 25 for P = .05

S.E. = ± 8.2

As these tables show there were significant differences between the mean yields of different grasses as well as between harvesting dates. This also occurred in the interaction between grasses and the date of harvesting, indicating that they did not all grow at the same rate.

The histograms show the mean yield of each grass week by week and the total of the four weekly means. The latter was used to express the individual results in relation to the highest total yield by showing each as a percentage of it. In case the employment of a total of weekly means should seem artificial it should be pointed out that it has a very practical application. If a given field is divided into four paddocks and each is grazed for approximately one week before passing on to the next, the total figure represents the available dry matter by the end of the first circuit of the paddocks. This does not account for regrowth that might have occurred but which would not have been used by then under a controlled rotational grazing system. Thus the total figure shows the maximum yield obtainable from each grass if grown in a pure stand. Most swards are a mixture of grasses and the results of this trial indicate which ones should be used if maximum spring output is desired.

The results are dominated by the performance of Danish Cocksfoot. This grass not only outyielded the total of every other grass but did so on each of the four weeks. Over and above it had a greater rate of gain from week to week than any of the others as is shown by the steepness of its growth curve. This curve, obtained by joining the top left hand corner of each pillar of a grass's histogram shows that cocksfoot's growth rate accelerated faster than the others. S 215 also shows this accelerating growth rate while Danish Italian and New Zealand perennial show virtually constant increase by straight line curves. The other grasses show varying degrees of growth rate acceleration.

In all cases the second week shows a slower rate of increase than the other weeks. This is apparent as a flat spot in the growth curve which destroys its smooth contour. Between the first and second cutting dates colder weather occurred which slowed down growth though it did not stop it. By interpolating the true expected level of the second week's yield a measure of the amount of growth repressed, or realisable potential lost could be obtained if desired.

Ayrshire perennial showed a high rate of dry matter production in the spring of 1957. It again did well in 1958 by outyielding the other ryegrasses but not the truly perennial grasses which were by then two years old and fully established.

New Zealand perennial ryegrass gave a disappointing performance and the lowest total yield. It seemed that this was not due to slowness of spring growth so much as death of tillers in the late part of the winter. If this was the true cause it would indicate a lower level of winter hardiness than the other ryegrasses possessed.

The Danish Italian was in its first harvest year having taken the place occupied by meadow foxtail in the 1957 trial. It too gave a poor yield especially when compared to its 1957 record. Its establishment had been good in 1957 but the new drills were possibly handicapped by the established grasses growing on either side of them. It was not possible to make a true comparison with 1957 but it seemed less productive than in the previous year. This impression may have been caused by the drills of the established grasses being slightly wider than the Italian due to the lateral spread of tillering. Whatever the reason it is certain that the aggregate of the growth conditions in 1957 suited Italian ryegrass best while in 1958 they suited cocksfoot best. It would be very valuable to compare these grasses when both had optimum conditions.

## SPECIES AND STRAINS REGROWTH TRIAL 1958

A second investigation was carried out on the eight grasses used in the last trial by measuring the regrowth that was available from each drill at the end of the four week trial period. In this way not only was the first cut yield known but also the total yield in the first four weeks for each treatment. A very comprehensive picture of the performance of each grass is therefore available from the combined results of both trials.

### Method and Materials

The actual harvesting took place on May 15th as soon as the fourth weekly cut of the growth rate trial was completed. The results of this last cut were used as a control since they expressed the yield available when growth was unhampered by previous defoliation. Three replicates were used and the results were subjected to statistical analysis. This showed a significant difference in the yields of different species, between the yields for different growth periods and also different rates of growth for given growth periods.

The figures are set out below and the important part of the results is shown in a histogram.

| Grass | Mean Yields in grams of dry matter from 9 feet of drill |
|---|---|
| Danish cocksfoot | 166 |
| S 215 | 139 |
| S 170 | 108 |
| Ayrshire perennial ryegrass | 89 |
| Rhenish tall fescue | 88 |
| S 24 | 80 |
| Danish Italian ryegrass | 64 |
| New Zealand perennial ryegrass | 40 |

Significant difference = 18 for P = .05  S.E. = ± 5.7

| Treatments | Mean Yields | Mean differences | | |
|---|---|---|---|---|
| Unhampered growth | 219 | | | |
| | | 135 | | |
| 3 weeks' regrowth | 84 | | 158 | |
| | | 23 | | |
| 2 weeks' regrowth | 61 | | | 196 |
| | | 38 | | |
| 1 week's regrowth | 23 | | 61 | |

Significant difference = 10 for P = .05

S.E. = ± 3.6

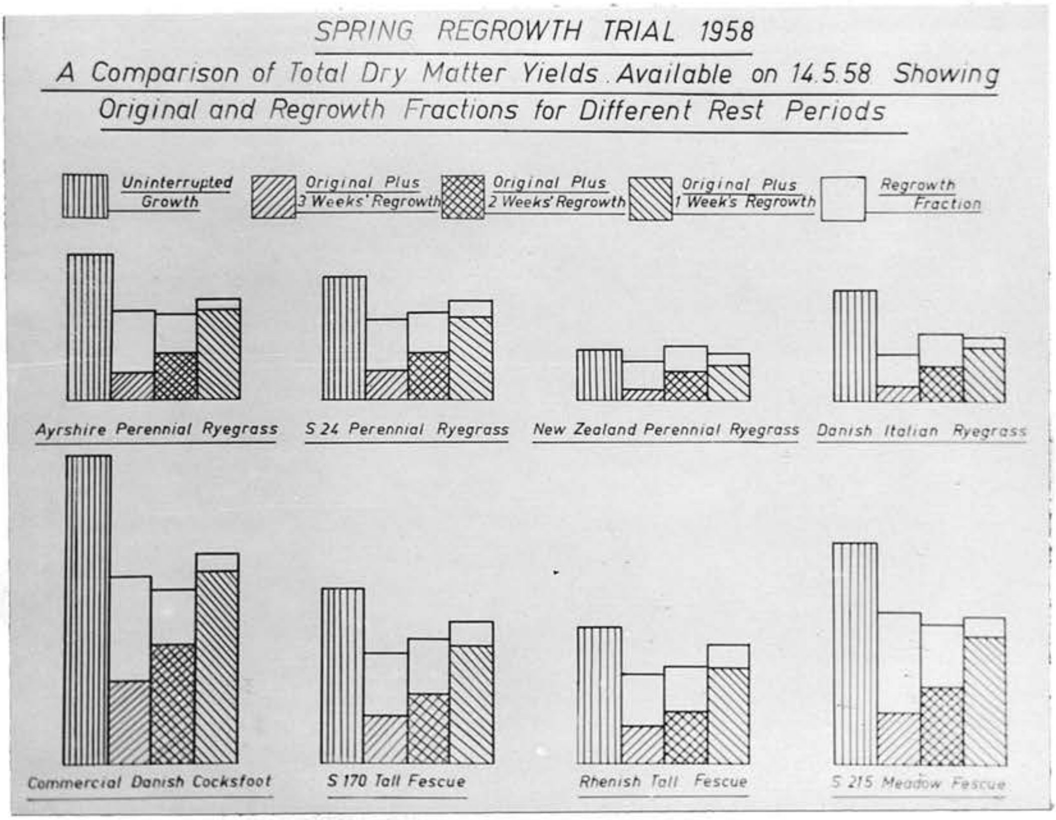
Interaction between length of growth period and strain of grass.

| Grass | Mean Yields | | | |
|---|---|---|---|---|
| | C | $R_3$ | $R_2$ | $R_1$ |
| Danish cocksfoot | 424 | 142 | 76 | 23 |
| S 215 | 306 | 138 | 86 | 26 |
| S 170 | 239 | 85 | 76 | 33 |
| Ayrshire perennial ryegrass | 201 | 85 | 54 | 17 |
| Rhenish tall fescue | 186 | 69 | 62 | 33 |
| S 24 | 171 | 71 | 54 | 23 |
| Danish Italian | 155 | 43 | 44 | 13 |
| New Zealand perennial ryegrass | 69 | 40 | 35 | 16 |

Significant difference = 29 for P = .05

S.E. = ± 10.2

C = control with unhampered growth
$R_3$ = 3 weeks' regrowth
$R_2$ = 2 weeks' regrowth
$R_1$ = 1 week's regrowth


SPRING REGROWTH TRIAL 1958
A Comparison of Total Dry Matter Yields Available on 14.5.58 Showing
Original and Regrowth Fractions for Different Rest Periods
Uninterrupted Growth
Original Plus 3 Weeks' Regrowth
Original Plus 2 Weeks' Regrowth
Original Plus 1 Week's Regrowth
Regrowth Fraction
Ayrshire Perennial Ryegrass
S 24 Perennial Ryegrass
New Zealand Perennial Ryegrass
Danish Italian Ryegrass
Commercial Danish Cocksfoot
S 170 Tall Fescue
Rhenish Tall Fescue
S 215 Meadow Fescue

The histogram shows the combined yields of regrowth plus first cut yields obtained in the growth rate trial. In every case unhampered growth and one cut clearly outyields the growth plus regrowth obtained in two cuts in the four week period. The more vigorously a grass is growing the greater is the difference in quantity of dry matter obtained. This is so even though the most vigorous grasses recover quickest and show the highest regrowth yields.

The general pattern of regrowth is constant for all the grasses. The defoliation of the first cut imposes a check which is shown by the small amount of regrowth that occurs in the next seven days. Taking cocksfoot as the extreme example the mean increase between the third and fourth week of unhampered growth was 153 grams. The regrowth that occurred in the same period from the drills defoliated after the third week was only 23 grams. Thus instead of the fourth week showing an increase in yield of almost 60% over the first three weeks' yield only 8% was produced. The check to growth was however only temporary. By the end of the third week the new growth was gathering momentum again. It seems quite certain that it would take several more weeks to catch up on the yield of the uncut grass and it is by no means certain that it could ever overtake it. The removal of herbage could almost be equated to the loss of a given number of growing days by this reasoning.

From previous investigations of protein content there is no question of a serious drop in quality occurring in this early spring period. If the aim is to maximise dry matter output the histograms show the undoubted advantage of waiting to the end of the four weeks and carrying out one defoliation rather than having two separate defoliations irrespective of the grass concerned.

Cocksfoot and meadow fescue which showed the highest week-by-week yields in the first part of the trial show the highest recovery yields also. In fact weekly yield ability seems to be directly related to recovery growth ability for the results placed the grasses in the same order for the two trials.

Ayrshire perennial had shown the highest regrowth yield of any grass in 1957 in the five weeks between March 28th and May 23rd. This characteristic was again apparent in 1958. The regrowth period was shorter and its yield was not equal to meadow fescue or cocksfoot but it shows a high recovery ability. This is apparent from the fact that its three weeks' regrowth plus one week's growth gives a slightly higher total than two weeks' regrowth plus two weeks' growth. In other words the third weeks' regrowth was equal to one week's normal growth prior to defoliation. Cocksfoot and meadow fescue are the only others showing the same trend in speed of recovery.

S 215 meadow fescue has done extremely well in this trial and in particular has outyielded the tall fescues. This seems unusual in view of the acclaimed hardiness and spring vigour of the latter. A possible reason for this result could be the rapid rise in temperatures after April 10th. If one allows that there is a minimum temperature below which no growth takes place it is easy to believe that different grasses could have different minima. The sudden large rise in temperature in the second week in April could have represented a change from conditions when no grass in the trial could grow to conditions in which they could all grow at maximum rate. If this was the case tall fescue's advantage of growing at a lower temperature than meadow fescue was lost. It also means that given a certain level of temperature meadow fescue can produce dry matter faster than tall fescue. This is a possible explanation but it must remain a matter for conjecture.

Conclusion

This trial and the previous one were felt to have been of high value not because they revealed something startling as much as gave a very detailed picture of a number of factors concerned in spring growth. The relation of cause and effect is clear cut and when shown graphically is easy to follow. These two trials combined constituted the largest investigation conducted, as far as number of results is concerned for they required the harvesting and processing of some two hundred and sixty samples in a four-week period. During the same period five other trials were harvested while preparations were being made simultaneously for sowing the 1959 trials. Also, this was achieved in spite of variable weather.

# SPRING FERTILISER TRIAL 1958

## Introduction

From the 1957 trial on potentiality for spring growth it was evident that the three ryegrasses, S 22 Italian, Danish Italian, and H I were capable of rapid growth in the early spring. As the differences between their yields with and without spring nitrogen were so great it was decided to carry out a critical test of the abilities of these three grasses to utilise adequate spring nitrogen.

Cocksfoot is generally held to be an early growing grass and for this reason an early strain, Danish cocksfoot was included in the trial although it had shown up so poorly in the potentiality trial. The reason for its poor production had appeared due to its slow establishment compared with the vigorous but short lived Italian type ryegrasses. As it turned out the cocksfoot gave interesting results.

## Materials and Method

Each of the four grasses were sown in randomised drills three drills together of each grass on April 24th, 1957. The whole was randomised throughout three replicates. Each of these blocks was subsequently subdivided crosswise into four subplots and each was allocated at random a different level of nitrogen fertiliser. The fertiliser used was nitro-chalk and the rates of application were 0, 2, 4, and 6 cwts. per acre. Special care was taken in applying it as the subplots were small. By choosing fertiliser rates as high as 6 cwts. per acre it was hoped to exceed the maximum which any of the grasses could utilise. In this way a bracket might be established containing the most advantageous rate of application.

Discards comprised one foot of each end of each subplot and one drill of each block. Thus the harvesting of each subplot comprised the yield from two neighbouring drills each nine feet long. In addition there were the usual discard drills along each end of the main plot.

The ground used was sandy and had been fallowed the previous summer. A soil analysis was made prior to sowing in February, 1957. The pH at 6.5 and the $K_2O$ level were satisfactory but the available $P_2O_5$ was low and so 21% superphosphate was applied at 5 cwts. per acre.

The customary procedure was followed for plot preparation, seed sowing and weed control. Establishment was rapid and only the cocksfoot was slow as usual. No fertilisers were applied in 1957 except the February application of superphosphate. Foliage was maintained uncut until the December cutting. Regrowth was good until cold weather in mid-January imposed a check, thereafter growth continued slowly at intervals until March.

On March 6th the nitro-chalk was applied to the subplots together with an application of 2 cwts. of sulphate of potash and 4 cwts. of 21% superphosphate per acre to the whole trial area. On the following day an intensely dry cold spell began with some snow. This lasted until April 10th. During this time it was very noticeable that the Italian ryegrass which had been very fresh in early March and about four inches high slowly shrivelled and looked brown by April. The cocksfoot on the other hand which was only about two inches long remained bright green throughout and very fresh. When mild weather came on 10th/11th April the cocksfoot was able to start growing within three days while the Italian had first to recover from the dry frost spell.

Results and Discussion

Harvesting took place on May 5th, approximately three weeks after growth had commenced. Cutting, weighing and drying followed the normal procedure and the dry matter yields were analysed statistically.

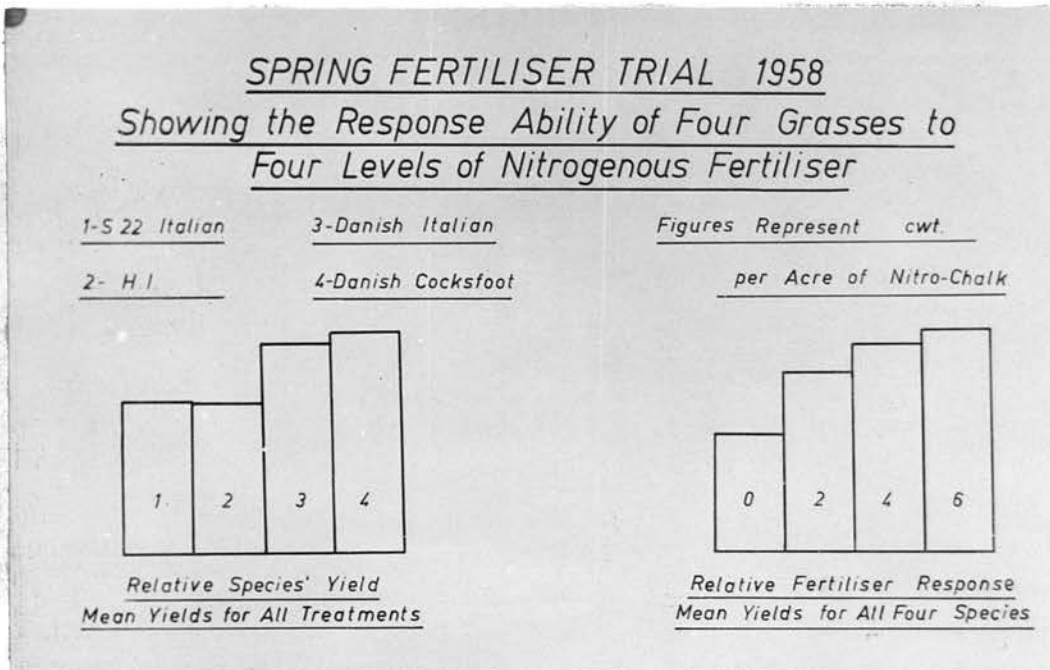
This analysis showed that there was a significant difference between the yields of the four grasses.

| Grass Strain | Mean Yield | Mean Difference in Yield | | |
|---|---|---|---|---|
| S 22 | 167 | | | |
| | | 1 | | |
| H I | 166 | | 61 | |
| | | 62 | | 75 |
| Danish Italian | 228 | | | |
| | | 14 | 76 | |
| Danish Cocksfoot | 242 | | | |

Significant Difference = 36 P = .05

S.E. = ± 10.4

From the table it can be seen that the yields fall into two groups. Danish cocksfoot gave the highest yield and Danish Italian only slightly less. H I and S 22 both had almost identical yields but were significantly lower than the other two. Both the cocksfoot and the Danish Italian were growing at an extraordinarily rapid rate when cutting took place. This is exemplified by their leafage being approximately twelve inches in length after only three weeks' growth and also by the dry matter content which in some cases was as low as 14%. It was not possible to say whether they were growing equally or



SPRING FERTILISER TRIAL 1958
Showing the Response Ability of Four Grasses to
Four Levels of Nitrogenous Fertiliser
1-S 22 Italian
2- H.I.
3-Danish Italian
4-Danish Cocksfoot
Figures Represent cwt.
per Acre of Nitro-Chalk
1. 2 3 4
0 2 4 6
Relative Species' Yield
Mean Yields for All Treatments
Relative Fertiliser Response
Mean Yields for All Four Species

whether the Danish Italian was catching up on the cocksfoot. The Italian was certainly superior to the cocksfoot before the severe cold of March began and also suffered a more severe check from it. However, the fact remains that in the first three week period cocksfoot outyielded the other grasses. That this came about by gaining an advantage from not dying in adverse weather while the others did, rather than positively outgrowing them from start to finish does not detract from the result at all. It means that under conditions as adverse as those ruling in March 1958 cocksfoot was the best of the four grasses in the trial. The real surprise lay in the fact that it was cocksfoot that showed this ability and that it outyielded the Italians after its very poor performance in the previous spring.

The effect of nitrogenous fertiliser is shown next.

| Treatment | Mean Yields | Mean Differences | |
|---|---|---|---|
| No nitro-chalk | 129 | | |
| | | 70 | |
| 2 cwts./acre nitro-chalk | 199 | | |
| | | 31 | 117 |
| 4 cwts./acre nitro-chalk | 230 | | |
| | | 16 | |
| 6 cwts./acre nitro-chalk | 246 | | |

Significant Difference = 27 for P = .05

S.E. = $\pm$ 9.3

These results are expressed in histogram form and show the customary response to successive increments of fertiliser. The first 2 cwts. increment shows a relatively large increase in yield and thereafter each further 2 cwts. shows diminishing returns. The 6 cwts. level gave the highest mean yield but it was not significantly greater than the 4 cwts. response.

It had been hoped to prove or disprove whether any of the four species was more responsive to high nitrogen fertility than the others. No significant interaction was found between grass variety and the quantity of nitrogen fertiliser applied. Any potential for such a response could have been masked by the rush of growth after the late spring.

Whether this was the case or not could only be shown by repeating the trial and hoping that the following spring's weather would be less abnormal. This was done with a slight modification to the layout of the trial.

The two important results from this trial are those shown in the two histograms. The first was the high yield of cocksfoot and the second was the pattern of fertiliser response to successive increments applied.

# AUTUMN FERTILISER TRIAL 1958

## Introduction

This trial concerned the study of autumn vigour and its effect on spring yield. It was carried out using autumn fertiliser and noting its effects in Spring. The grasses employed were the same four used in the spring fertiliser trial and the fertiliser was nitro-chalk applied in August. The concept underlying this trial was complementary to the previous one. If grasses have a differing ability to grow rapidly and yield a large quantity of dry matter in spring then this could be influenced by their vigour at the beginning of spring carried over from the previous autumn.

## Materials and Method

The grasses were sown on the same date as the previous trial namely April 24th, 1957. The same procedure of sowing three rows together of each grass was also followed. The difference in treatment was to apply nitro-chalk at 3 cwt. per acre to eight of the sixteen subplots in August, 1957. Thereafter no further nitro-chalk was applied before harvesting took place in spring. Due to the small space available in the trial area, there was insufficient discard between replicates to allow a properly randomised application of fertiliser to be given. This was unfortunately due to a misunderstanding in the original layout of the trial. No statistical analysis is therefore given though the results are set out and can be scrutinised critically in other ways.

Results and Discussion

The response to the early August application of nitro-chalk was rapid. In six days a deepening of foliage colour was noticeable where the nitro-chalk had been applied. This colour difference continued to intensify and remained visible until late November. Within ten days of its application extra growth was visible in the darker green areas. The total autumn response to nitro-chalk was very great and its effect was visible until all the herbage was removed by the December defoliation. At this point the cut material was weighed and dry matter estimations made so that an analysis could be undertaken. The chief value in this was to indicate the relative productive vigour of the four grasses up to that date. It also provided a measure of apparent vigour in autumn.

After the December defoliation recovery was rapid and the new growth was almost an inch high when cold weather in mid-January stopped further increase. Cold spells followed on and off until March with the soil frozen at times. When the cold dry weather of March began the ryegrasses which had received nitro-chalk in autumn looked less vigorous than those which had not. The cocksfoot on the other hand showed little difference in vigour between the two treatments. By the time active growth began in mid-April the effects of the autumn nitro-chalk were very plain. The cocksfoots were very vigorous while many of the ryegrass tillers and even whole plants were dead. H I and S 22 looked even poorer than the Danish and the yields bore no relation to those obtained in December.

The spring growth was harvested and dry matter estimations were made in the usual way. Two dates of harvesting were used the first on April 24th and the second on May 8th.

The overall increase to autumn dry matter production from nitro-chalk was 44%. There were, however, considerable variations between the increases it produced in the different grasses. The highest yield with and without nitro-chalk was achieved by Danish Italian and the relative yields of the others are expressed below as a percentage of its yield.

| Strain | - N | + N | Total for both treatments |
|---|---|---|---|
| Danish Italian | 100% | 100% | 100% |
| S 22 | 74% | 96% | 86% |
| Danish cocksfoot | 18% | 40% | 30% |
| H I | 66% | 74% | 70% |

The largest increase in dry matter yield arising from nitro-chalk was given by S 22. When the increase was expressed as a percentage of the unfertilised yield cocksfoot gave the greatest percentage increase but then its unfertilised yield was very low.

| Strain | % increase of + N over - N |
|---|---|
| Danish Italian | 20% |
| S 22 | 56% |
| Danish cocksfoot | 161% |
| H I | 34% |

These results correspond with the 1956 trial of establishment vigour in which the Italian ryegrasses were supreme.

In the spring results Danish cocksfoot gave by far the greatest overall yield because it had suffered no winter killing. The following table shows the degree of difference in yields and the similarity between S 22 and H I's winter hardiness.

| Grass | % yield relative to cocksfoot |
|---|---|
| S 22 | 19% |
| H I | 19% |
| Danish Italian | 49% |
| Danish cocksfoot | 100% |

The actual yield from the Danish cocksfoot averaged almost exactly 100 grams of dry matter per foot of drill.

The growth rate was not the same for each grass between the two harvesting dates as the following table shows.

| Grass | % increase in yield in 14 days to May 8th |
|---|---|
| S 22 | 7% |
| H I | 75% |
| Danish Italian | 9% |
| Danish cocksfoot | 21% |

The H I showed a remarkable increase compared with the others but as there were so few live tillers this increase is not very significant. Its gross yield on May 8th was only half that of Danish Italian.

The effect of autumn nitro-chalk on each grass was quite clear as the next table shows.

| Grass | Difference in yield produced by autumn nitro-chalk |
|---|---|
| S 22 | - 57% |
| H I | - 48% |
| Danish Italian | - 34% |
| Danish cocksfoot | + 34% |

In every case the Italian ryegrasses were depressed in yield by autumn nitrogen while cocksfoot benefited. As even the Italian drills which had received no autumn nitrogen showed some death of tillers and so even though the unfertilised drills yielded more than the others this yield was still not very good. The death among the unfertilised plants was puzzling, because they had received identical treatment to those in the spring fertiliser trial in which no killing occurred. It was concluded that this slight difference might have been due to greater frost damage to the autumn fertiliser trial plot since it was situated on slightly lower ground. This had perhaps created "frost-pocket" conditions.

Conclusion

The outstanding things about this trial were that autumn nitrogen applied to Italian ryegrass had almost annihilated the plants after a cold winter. This was noticeably worse with S 22 and H I than Danish Italian. On the other hand the same treatment proved beneficial when applied to cocksfoot. This indicates some major difference not merely in the hardiness of the two grasses but in their basic physiology.

## AUTUMN RESTING TRIAL ON MIXED SWARD 1958

### Introduction

In the first season winter-resting had produced positive gains to spring yield so it was decided to repeat the previous trial using the same defoliation and resting techniques but conducting the pre-treatments in autumn instead of in winter.

### Materials and Method

After the spring trial of 1957 the trial area was left to grow unchecked until late June. By that time the grasses had all shot into ear and the effects of the spring nitrogen were no longer visible. In late June the whole area was mown with the Allen cutter and the herbage removed. Regrowth was moderately good but most important of all the sward was very uniform in appearance. As this was so it was felt justifiable to re-use the same area. No other sward was available in its place and it would not have been possible to reseed the area in May and start resting treatments in August.

The three resting treatments were from the first week of August, September and October respectively until mid-December when the usual clearance of autumn foliage took place. Beginning in August each plot was cut with the Allen autoscythe once a month until its resting began. In this way August to December rested plots were cut once in August before resting began but October to December rested ones were mown three times in August, September and October. This cutting treatment represented in a general way rotational grazing once in four weeks which would normally be the alternative treatment to resting a grazing pasture.

Growth during August was good but thereafter the sward showed lack of further vigour in spite of the mild autumn. The little wild white clover that had formerly been present had been suppressed by the lenient spring treatment and the whole area seemed lacking in available nitrogen.

The layout was the same as in 1956/57, namely, two harvesting dates for three resting pretreatments with two levels of spring nitrogenous fertiliser. The whole was replicated four times giving forty-eight subplots each three yards wide by eight yards long. It would have been desirable to refine the layout slightly and so gain more information about the resting or the fertiliser treatments. This could have been done by eliminating the two harvesting dates which were felt to be unnecessary. However, it was decided to maintain the layout plan unaltered to avoid the risk of complications.

On March 11th each subplot was top-dressed with 21% superphosphate and sulphate of potash each at 3 cwts. per acre. The twenty-four subplots due to receive nitro-chalk each had it applied at 3 cwts. per acre. This fertiliser was quickly washed into the soil but cold weather prevented much growth response.

By May 1st growth was still not long enough to cut with an Allen autoscythe. Instead of following the time-consuming method of cutting samples with hand shears as in 1957, a modified Tarpen hedge-cutter with a collecting-pan behind the cutting-blade was tried. It was found to be very suitable for close cutting of herbage and produced an effect very similar to that obtained with shears. The Tarpen blade was twelve inches wide and so nine cuts each twelve inches long were made in each subplot. This gave a total cut of one square yard per plot. All the herbage from which was bulked together.

The first cut was made on May 1st. and the second on May 20th. The first cut was made before cattle in the area had been put out to grass. Due to the very late spring most were put out in the second week of the month but the farm pastures were still very bare. The second cutting date though much later represented approximately the same stage of growth as the corresponding cut in 1957. From this the 1958 spring season was not less than a fortnight later than the 1957 spring.

Except for the use of the Tarpen cutter all harvesting weighing and drying was done in the same way as in 1957.

Results and Discussion

The important part of this trial concerned the effect of different amounts of autumn rest on spring yield. The results showed no significant difference between the three autumn treatments. This is not what would be anticipated after the positive results of the previous winter-resting trial. Nor is it the result that one would expect from the general recommendations to rest in autumn for extra spring yield that are to be found in the literature. The result obtained could have been due to the very long and late winter period experienced in the spring of 1958 compared to 1957. Although this may have played a part it was felt that the lack of autumn vigour also contributed to it. This feature has already been remarked upon and it can be reasoned that by growing slowly when resting took place only small amounts of food reserves were accumulated. This could explain the similarity in the results for the three different pretreatments if it were the real reason.

It was decided to test this idea by repeating the autumn pretreatments and at the same time ensuring that the autumn growth would proceed vigorously by applying nitrogenous fertiliser. If no significant benefit was then obtained from the resting treatments it would indicate that a sward does not carry over reserves derived from lenient autumn treatment until spring. If they do carry reserves over in sufficient quantity to affect the spring production it might be possible to see if this was large enough to warrant careful autumn management. It could happen that there was a carry-over but the extra yield derived might not be worth while. To answer this required a further trial.

The trial did yield three significant results the first of which showed the effect of later harvesting was to yield more dry matter.

| Treatment | Mean Yield | Mean Difference |
|---|---|---|
| Late cut | 238 | 130 |
| Early cut | 108 | |

Significant difference = 38 for P = .05

S.E. = $\pm$ 7.3

The second showed the spring application of nitro-chalk increased the yield.

| Fertiliser Treatment | Mean Yield | Mean Difference |
|---|---|---|
| + nitro-chalk | 214 | 84 |
| - nitro-chalk | 130 | |

Significant difference = 22 for P = .05

S.E. = $\pm$6.4

Lastly there was an interaction between the effects of the fertiliser and time of harvesting. This in fact meant that the fertiliser gave a greater increase in yield between the two harvesting dates than occurred without it.

| Treatment | Mean Difference between the two cutting dates | Mean Difference between the two treatments |
|---|---|---|
| + nitro-chalk | 165 | 75 |
| - nitro-chalk | 90 | |

Significant difference = 44 for P = .05

S.E. = $\pm$ 12.8

The conclusion was that autumn vigour probably did much to determine a sward's ability to carry over reserves until spring and that this should be put to practical test by a further trial.

## AUTUMN RESTING TRIAL ON ITALIAN RYEGRASS SWARD

## 1958

### Introduction

The strain potentiality trial using drilled grasses that was laid down in 1956 had indicated that the Italian ryegrasses possess a very high potential for early growth. In view of the differences between drilled and sward conditions it was felt desirable to pursue the study of Italian ryegrass in a sward trial.

The winter resting pretreatments at Fulford had also shown promising results even though the pasture was an old one and slow to start spring growth. There was a real need to repeat these resting treatments on a vigorous and responsive young sward. The difficulty of using a ley mixture is that all the species and strains are seldom early types. Not only is it very difficult to know how much each ingredient has contributed to a given yield in these conditions but its power to contribute to the total yield is diminished as its percentage of the total composition of the sward is reduced. In other words the more early strains are diluted in a mixture by late strains the less the mixture can produce at an early date. As this study is concerned with pasture for a special purpose a single species sward was desirable. From the results of the two trials mentioned Italian ryegrass was the natural choice for this sward. One strain of Italian namely Danish was employed.

### Materials and Methods

The new trial was sown at Easter Howgate on April 24th 1957 using 25 lb. of seed per acre. The intended treatment and hence the layout was similar to the Fulford trial area. By having two dates about a fortnight apart for the harvesting of the spring material the risk of cutting too soon before the effects of different treatments have shown is minimised. Half the total area was cut at each date. These two treatments were next split to allow of spring nitrogen fertiliser at the rate of 3 cwts. of nitro-chalk per acre and a control of no nitrogen. Each of these plots were then split into three and each subplot allocated at random a different resting treatment. The three resting treatments were from the first week of August, September or October respectively until mid-December when the usual removal of autumn foliage took place. Beginning in August each plot was cut with the Allen once a month until its resting began.

Each subplot measured 2 yards by 10 yards long which after allowing for discards gave a sampling strip of 8 yards by 1 yard. All treatments were randomised and replicated three times. After germination took place 2 cwts. per acre of nitro-chalk was applied in May to assist rapid establishment. By late June a thick sward had grown up and the few weeds that appeared were scythed off. The plots were uncut until the pretreatments began in August.

In the spring of 1958 on March 11th sulphate of potash and superphosphate was applied to all plots and those plots due to receive nitrogenous fertiliser received nitro-chalk at 3 cwts. per acre. Due to the cold dry spell that followed no visible growth began until about April 14th. The first cutting was on April 29th and the second on May 9th. The Allen cutter was used and the fresh material was weighed in the field to the nearest ounce. Fresh samples were taken in the field for laboratory estimation of dry matter content.

Results and Discussion

The dry matter yields were analysed statistically. The two harvesting dates and the two fertiliser treatments gave significant differences in yields which is in keeping with the results of other trials.

| Treatment | Mean Yield | Mean Difference |
|---|---|---|
| late harvesting | 29 | 15 |
| early harvesting | 14 | |

Significant Difference = 9 for P = .05

S.E. = ± 1.4

| Treatment | Mean Yield | Mean Difference |
|---|---|---|
| + nitro-chalk | 27 | 15 |
| - nitro-chalk | 14 | |

Significant Difference = 6 for P = .05

S.E. = ± 1.4

The resting pretreatments were the chief concern of the trial and they gave significant results.

| Treatment | Mean Yields | | Mean Difference |
|---|---|---|---|
| Rested from August | 15 | 9 | 10 |
| Rested from September | 24 | 1 | |
| Rested from October | 25 | | |

Significant Difference = 4 for P = .05

S.E. = ± 1.4

The figures above show a negative response to resting. That is resting had a detrimental effect on spring yield and the longer the autumn rest the poorer the spring yield. This rather confounds the opinions expressed in the literature on the effects of autumn management. The actual yield figures only express what was evident from a visual inspection of the plots. When the autumn foliage was removed in December the differences caused by the three resting treatments was apparent. The long rested plots had fewer tillers per plant than the others and were slower in recovering from this defoliation. Even in March they still looked less vigorous than the others. Some winter-killing of tillers had occurred in the latter but this had not affected entire plants. The quantity of autumn growth that occurred after early September was evidently not great. It was certainly insufficient to make any significant difference to the spring production of plots rested from September onwards compared to those rested from October onwards. This in itself indicates that any management treatment must take place while autumn growth is still active if it is to affect spring growth. Also, it seems to indicate that August is the latest month when really active growth is occurring for this purpose in the Edinburgh area.

There was an interaction between the autumn resting effect and the date of harvesting.

| Treatment | Mean Difference between late and early harvesting | Mean difference between treatments | |
|---|---|---|---|
| Rested from August | 9 | 10 | |
| Rested from September | 19 | | 9 |
| Rested from October | 18 | 1 | |

Significant difference = 8 for P = .05

S.E. = $\pm$ 2.8

This shows that the plots rested from September onwards made most rapid growth once spring growth started. From this it can be deduced that there is a happy medium between inducing short tillers by frequent autumn defoliation and long tillers by lack of defoliation. This result is quite straightforward if considered alone but it raises a problem if considered in conjunction with the other results of the trial. The problem is how to define spring vigour. This result indicates that one treatment produces faster growth in the spring period while a different treatment, namely a still shorter rest period produces more dry matter by a given date. For practical purposes which treatment would be best? The problem is probably most easily disposed of by remembering that the real aim of this study is to produce the maximum dry matter at the earliest possible moment. This will also serve to clarify the meaning of spring vigour.

The analysis also revealed a highly significant triple interaction between resting treatments, harvesting data and fertiliser treatment. This is not surprising in view of the level of significance of the separate interactions of fertiliser and harvesting date with the resting treatments.

The findings of the whole trial were possibly influenced to a large extent by the particular climatic conditions prior to May, 1958 but the results are very valuable nevertheless. In particular the trial has helped to diagnose the influence of certain factors that affect spring growth. At the same time it provides a new problem by indicating that autumn resting can be deleterious. The question is why?

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At the end of the 1958 spring trial period it was possible to say that each of that season's trials had yielded something of value. At the same time almost all these trials had posed some new major problem. For instance, why had cocksfoot outyielded Italian ryegrass in 1958 but not in 1957? Was this due to the weather conditions or something else? Then there was the negative response to autumn rest which ran counter to established opinion on the value of autumn management. That too required further study. Above all the abnormally late spring of 1958, though it may have averaged out with the abnormally early one of 1957, created conditions of growth and produced results which could not be considered typical of a normal spring. For this reason the trials with spring and autumn application of nitro-chalk on four selected grasses were repeated in 1959, though in altered form. The study of autumn nitrogen was extended to cover its effect when combined with autumn resting treatments on mixed sward and on pure Italian sward. The ability of Italian ryegrass to establish quickly and yield large quantities of herbage made it worthy of a special trial in which all the available strains of Italian ryegrass could be compared. The species and strains growth rate trial was developed into a trial to assess spring nitrogen response ability.

This series of trials was set in train for the spring of 1959. However, a little later, in the course of private communication with H.K. Baker who was studying early spring growth at the Grassland Institute at Hurley, several important facts came to light from his results. Earlier findings published by Baker, who had been investigating this line of work since 1954, were mentioned in the review of literature in Section I. The additional information was contained in a series of unpublished reports. Among other things these showed that in 1955 and 1956 he had found little benefit from different periods of autumn rest on herbage yield in the following spring. When autumn nitrogen was applied a slight increase in spring yield occurred but not equal to the increase from the same amount of nitro-chalk given in spring.

Later it became apparent that swards dominated by cocksfoot and by ryegrass reacted differently. The predominantly cocksfoot swards showed some benefit in spring from autumn rest and a slight benefit from autumn nitrogen. In contrast the yields from ryegrass dominated swards were greatest when given a short rest in October only. Autumn applications of nitro-chalk added little to their spring yield and when combined with a long autumn rest depressed the spring yield.

In a published note on the influence of previous management on the death of perennial ryegrass in winter Baker (1956) was able to state some useful conclusions. For instance the longer the rest period in the previous season the greater the amount of winter-killing. The effects were more serious in sward-grown than spaced plants. The strain used was S 24 and it was found that the closer to the ground the spaced-plant shoots were cut the weaker was the regrowth and the greater the death-rate. As the spaced plants were less damaged than those in sward under the same treatment, frost alone could not be the reason for death. He concludes that excessive autumn growth can cause elongation of the basal internodes and thus elevation of the growing points and roots so that they suffer from frost. It is possible that this elevation is not merely a mechanical process but is caused by the restriction of light reaching the plant bases. The shading effect of dense autumn herbage also seems to inhibit new tiller formation at the plant bases which results in the plants' death when the old tillers are killed or removed. In support of the idea of exposure of the growing points Baker quotes Tavcar (1930) who found that the hardiest wheat, barley and oat varieties were those with their growing points below soil level.

Baker, in further unpublished work concerning the effects of autumn resting and nitrogenous fertilisers on Italian ryegrasses found similar results to those for perennial ryegrass. He used the three strains S 22, HI and commercial Italian and found a similar reaction from all three. The effect on crude protein output of autumn nitrogen plus resting was to depress the spring yield. This was depressed still further if spring nitrogen was added as well. In this way the pattern for crude protein and dry matter was very similar. This is not so in the mid-summer period when the crude protein content varies inversely with the dry matter due to ageing of the plant tissues.

In comparisons between the three strains employed, S 22 gave the highest spring dry matter yield under every treatment. The commercial Italian consistently occupied second place and H.I. gave the poorest yield. This was not the case in the trials carried out at Edinburgh. The difference may lie in climate or in the type of commercial Italian Baker used.

This whole series of trials provide a rich fund of information on the very topics under study in this volume. In themselves these results provide many conclusions but they provide even more when related to the trials so far recorded. An explanation for the high mortality of the Italian ryegrasses treated with nitro-chalk in the autumn fertiliser trial is afforded. Evidence supporting the negative benefit to Italian ryegrass sward from autumn resting is given. The observed reduction in tillering in the same trial is substantiated and the distinction between ryegrass reactions and cocksfoot is shown to rest upon fundamental differences in plant anatomy and physiology.

It was a great pity that this wealth of information arrived too late to be incorporated into the 1959 series of trials. It would have been of great interest to test some of Baker's findings under Scottish conditions as there would possibly be some variations. The placing of the strains in his Italian ryegrass trial affords an example of this. As the following description of the 1959 trials will show several of the lines of study being followed were similar to Baker's though not identical to his.

## SPECIES AND STRAINS FERTILISER TRIAL 1959

### Introduction

Three replicates of the species and strains growth rate trial were retained in 1958 and subjected to a spring fertiliser trial in 1959. The fertiliser used was nitro-chalk and the aim was to discover the response potential of each grass to varying levels of nitrogen fertility. At the same time it afforded a measure of species and strain growth ability for perennial grasses in their third spring. By re-seeding the short-lived Italian ryegrasses that had been present in the previous trial a comparison was possible between them and the perennial grasses.

### Materials and Method

After the growth rate trial ended in the spring of 1958 all the drills that were to be replaced were dug and re-seeded. The grasses that were retained were :

| | |
|---|---|
| Ayrshire perennial | Danish cocksfoot |
| S 24 | Rhenish Tall Fescue |
| New Zealand perennial | S 170 |
| S 215 | |

New drills were established of :

| | |
|---|---|
| S 22 | Danish cocksfoot |
| Danish Italian | S 37 |
| H.I. | |

The usual summer treatment was followed of suppressing weeds and allowing growth to go unchecked until December when the foliage was removed. In the first week of March, 1959 each replicate was divided crossways into four subplots and to each of these was allocated at random a different amount of nitro-chalk. The rates used were nil, 2, 4 and 6 cwts. per acre. The spring growth was harvested on the 21st of April, dry matter assessments were made and the results subjected to a statistical analysis.

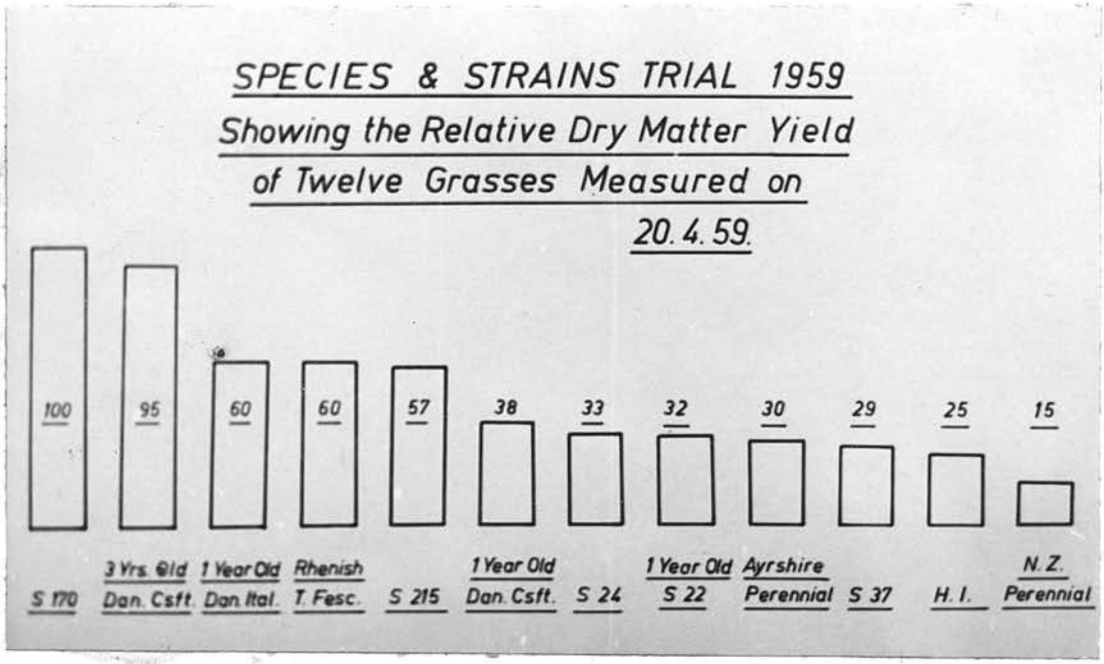
## Results and Discussion

There were significant differences between the yields of different grasses as their mean yields show.

| Grass | Mean Yield |
|---|---|
| S 170 | 204 |
| Established Danish cocksfoot | 190 |
| Danish Italian | 120 |
| Rhenish tall fescue | 119 |
| S 215 | 115 |
| New Danish cocksfoot | 75 |
| S 24 | 65 |
| S 22 | 64 |
| Ayrshire perennial | 60 |
| New S 37 | 58 |
| H I | 51 |
| New Zealand perennial | 30 |

Significant difference = 38 for P = .05

S.E. = $\pm$ 13.5


SPECIES & STRAINS TRIAL 1959
Showing the Relative Dry Matter Yield
of Twelve Grasses Measured on
20. 4. 59.
100
95
60
60
57
38
33
32
30
29
25
15
S 170
3 Yrs. Old Dan. Csft.
1 Year Old Dan. Ital.
Rhenish T. Fesc.
S 215
1 Year Old Dan. Csft.
S 24
1 Year Old S 22
Ayrshire Perennial
S 37
H. I.
N. Z. Perennial

These results show several things. Firstly cocksfoot and S 170 tall fescue have justified their reputation as early grasses with high productive potential. Though Danish cocksfoot had been able to do this by its second season in 1958, S 170 had reached its third spring in 1959 before it did so. S 170 was also able in this trial to exhibit its superiority over Rhenish tall fescue. The comparison between these three grasses and S 215 was a fair one because all the established grasses had spread slightly so that their drills were wider than the newly sown ones. The degree of spread influenced their ability to give high yields because of the extra tillers present in a widely spread drill. This problem occurred in other trials and made the task of comparing established with newly-sown drills very difficult. It is a problem peculiar to drilled trials that would not occur in swards. Cocksfoot and tall fescue were particularly prone to lateral spreading and the ryegrasses and meadow fescue less so. S 215 meadow fescue again did well though its yield did not rival that of Danish cocksfoot in this trial as it had done in 1958. Danish Italian was definitely the highest yielding ryegrass and the best of the resown grasses. New Zealand perennial ryegrass gave a very low yield as its tillers seemed to be weak and tended to die out.

(See table overleaf)

| Fertiliser Treatment cwts. per acre | Mean Yields | Mean differences |
|---|---|---|
| 0 | 904 | |
| | | 232 |
| 2 | 1136 | |
| | | 85 |
| 4 | 1221 | |
| | | 121 |
| 6 | 1342 | |

Significant difference = 21 for $P = .05$

S.E. = $\pm$ 7.4

There were significant differences between the effects of the different fertiliser treatments though there was no interaction between strain and fertiliser effect. The mean yields for fertiliser show that the smallest difference is between the effect of 2 and 4 cwts. of nitro-chalk. This seems to be only a temporary pause in the rate of increase for the general trend towards increase continues steadily to the 6 cwts. per acre level. This can be seen when the rate of increase at each rate of fertiliser application is expressed as a percentage of the unfertilised yield. In this way the 2, 4 and 6 cwts. applications produced 26%, 35% and 48% increase respectively.

## Conclusion

The most useful feature of this trial was that it enabled comparisons to be made between established perennial grasses in spring thus completing the three year study of species' spring potential. It also indicated that any further study of the particular grasses involved would be best done under sward conditions.

# ITALIAN RYEGRASS STRAIN TRIAL 1959

## Introduction

The enormous vigour and productive capabalities of Italian ryegrass coupled to its earliness of growth made it worthy of a separate strain trial. In this, as many available strains as possible were collected and sown in drills to compare their productive capacities in spring. As cocksfoot had yielded so well in 1958 several drills were included in the trial.

## Materials and Method

The new trial was sown on May 29th, 1958 using one of the two large plots on which the species and strains growth rate trial had been conducted.

In some earlier trials cocksfoot had proved to be at a disadvantage in its first spring compared to Italian ryegrass. This was due to its typically perennial habit of slower establishment. To overcome this disadvantage, when the trial area was ploughed in preparation for seeding, the established drills of Danish cocksfoot were retained from the former trial. These were three in number which corresponded to the replications of the new trial. As they were two years old they were already fully established. The ploughing was carried out to within six inches of these cocksfoot drills but this, plus some rough treatment in the subsequent harrowing operations seemed to do them little harm.

The strains employed in the trial were as follows -

Italian ryegrasses.

| | |
|---|---|
| S 22 | Irish |
| Danish | New Zealand mother |
| Melle | H.I. |
| 486 | Danish cocksfoot (2 yeard old) |
| Imperial | Danish cocksfoot (new seeding) |
| Hinderupgaard | |

Westernwolths ryegrass was sown as a discard between the replicates. In this way it could be observed beside the other grasses even though no results were obtained from it. It acted in truly annual form by growing well until November 1958 and having flowered by then the plants died.

Establishment of all the new drills was very rapid and even. Weeds were suppressed by hoeing during the summer. No nitro-chalk was given until the spring of 1959. When defoliation took place on December 5th weighing and dry matter sampling of the Italian ryegrass herbage was carried out. The results of this were then analysed statistically to give a measure of the establishment vigour of each grass. This was thought worthwhile as there appeared to be differences between the grasses by that date.

Recovery was good but growth was held in check by the six weeks of very cold weather that began in early January. No visible winter killing occurred in spite of this.

In the first week of March each replicate was divided into four subplots and to each was allocated at random a different rate of nitrogenous fertiliser. The fertiliser used was nitro-chalk and rates of application were nil, 2, 4 and 6 cwts. per acre. This enabled an estimate to be made of productivity under varying levels of fertility. Any differential ability between the strains could also be seen. A uniform application of superphosphate and sulphate of potash was also given. Harvesting the spring material took place on the 16th of April.

Results and Discussion

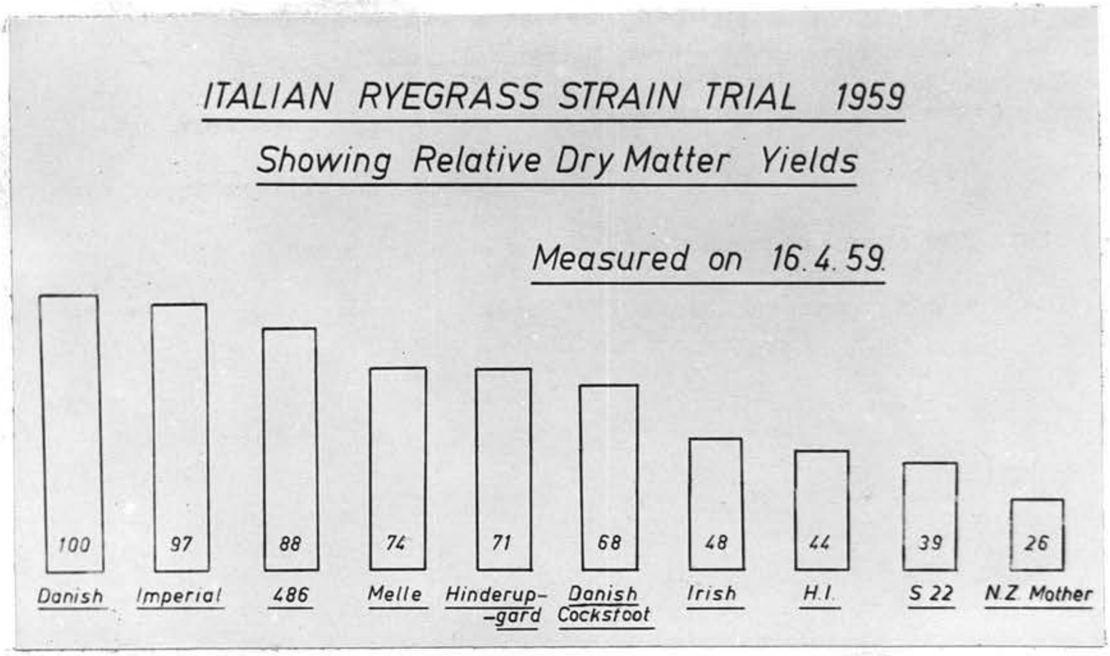
In the December estimations significant differences between the dry matter yields of different strains occurred. The results are set out below.

| Strain | Mean Yield |
|---|---|
| H.I. | 512 |
| Irish | 488 |
| S 22 | 469 |
| Melle | 425 |
| Danish | 419 |
| N.Z. mother | 411 |
| Imperial | 392 |
| 486 | 380 |
| Hinderupgaard | 269 |

Significant difference 93 for $P = .05$

S.E. $= \pm$ 31

The retention of established cocksfoot drills had one drawback. That was, that in spite of cutting off the flowering-heads during the summer these drills did exert a shading effect on the drill next


ITALIAN RYEGRASS STRAIN TRIAL 1959
Showing Relative Dry Matter Yields
Measured on 16.4.59.
100
97
88
74
71
68
48
44
39
26
Danish
Imperial
486
Melle
Hinderup-gard
Danish Cockstoot
Irish
H.I.
S 22
N.Z. Mother

to them. As the direction of the drills was east to west only one ryegrass drill on the north side of each cocksfoot drill was affected. The difference was barely noticeable but as the random layout had placed two of the three replicates of hinderupgaard in this position it may have been unduly penalised. The yield from its third replicate was higher than its mean yield and almost equal to the mean yield of S 22.

In the spring assessment significant differences were obtained again between strain yields and also between fertiliser treatments. In this instance the cocksfoot yields were included. The results shown below are also expressed in a histogram.

| Grass Strain | Mean Yield |
|---|---|
| Danish cocksfoot (established) | 176 |
| Danish Italian | 105 |
| Imperial | 102 |
| 486 | 93 |
| Melle | 78 |
| Hinderupgaard | 75 |
| New Danish cocksfoot | 72 |
| Irish | 51 |
| H I | 47 |
| S 22 | 41 |
| N.Z. mother | 28 |

significant difference = 31 for P = .05

S.E. = $\pm$ 10.4

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| New Danish cocksfoot | 72 |
| Irish | 51 |
| H I | 47 |
| S 22 | 41 |
| N.Z. mother | 28 |

significant difference = 31 for P = .05

S.E. = ± 10.4

| Fertiliser treatment (nitro-chalk cwts. per acre) | Mean Yields | Significant differences |
|---|---|---|
| 0 | 55 | |
| 2 | 82 | 27 |
| 4 | 88 | 33 |
| 6 | 91 | 36 |

significant difference = 10 for P = .05

S.E. = $\pm$ 3.6

No interaction between strain and fertiliser treatment was apparent in the analysis.

In the mean strain yields the established cocksfoot shows how its long establishment was of advantage. This is another instance of extra tillers in a drill influencing yield ability. The established cocksfoot drills were almost twice as wide as the ryegrass drills which explains its relatively enormous yield. For this reason it is not shown in the histogram comparison as its conditions of growth were so dissimilar to the other grasses.

Among the other grasses the surprising thing is the extent of scatter of the results. The total yields were small because this trial was harvested as soon as growth was about six inches high. However, there is no reason to believe that this should have penalised one grass more than any other or affected the degree of scatter. Nevertheless the uncomfortable feeling persists that a strain like S 22 which has previously been found similar to Danish in yield ought to have done better. When the results for individual grasses are scrutinised drill by drill some of them show considerable variations between replicates. For these reasons this trial would have been repeated on a fresh site without established cocksfoot if another season had been available. It is difficult to see why these results should be erroneous but it would be desirable to check them before using them as a basis for pronouncing the relative merits of each strain involved.

# SPRING FERTILISER TRIAL 1959

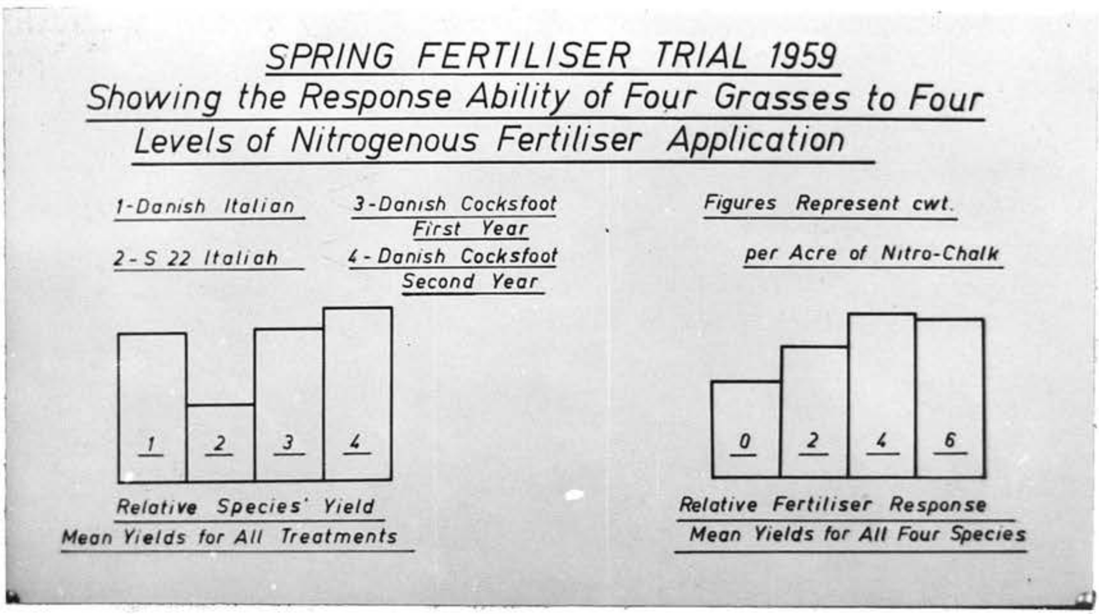
## Introduction

After the abnormal spring of 1958 which undoubtedly affected the results of the spring fertiliser trial in that year it was decided to repeat it in 1959. Danish cocksfoot and Italian ryegrasses were again employed and the aim was to compare their yields under different levels of nitrogen fertility by applying nitro-chalk in spring.

## Materials and Method

H. I. ryegrass had not yielded well in the 1958 trial and as it had never equalled S 22 or Danish Italian in yield in any trial it was not included in the 1959 trial. S 22 and Danish Italian were retained and so was Danish cocksfoot which had done so well in 1958. As the same trial area was to be used for the new trial the established cocksfoot drills were retained for 1959 when the area was ploughed. A new seeding of Danish cocksfoot was included in place of H.I.so that both one and two-year-old cocksfoot could be compared with the one-year-old S 22 and Danish Italian.

The reseeded grasses were allocated at random within each replicate and the former practice of growing three drills of each,side by side in each replicate was followed. The new trial was seeded on May 28th, 1958 and established quickly. The usual summer treatment was given with defoliation at the end of the season in December. No fertiliser was applied until 4th March, 1959 when sulphate of potash and superphosphate were applied. Nitro-chalk was allocated at nil, 2, 4 and 6 cwts. per acre at random to the four subplots in each replicate.


SPRING FERTILISER TRIAL 1959
Showing the Response Ability of Four Grasses to Four Levels of Nitrogenous Fertiliser Application
1-Danish Italian
2-S 22 Italian
3-Danish Cocksfoot First Year
4-Danish Cocksfoot Second Year
1
2
3
4
Relative Species' Yield
Mean Yields for All Treatments
Figures Represent cwt.
per Acre of Nitro-Chalk
0
2
4
6
Relative Fertiliser Response
Mean Yields for All Four Species

Harvesting took place on April 15th, 1959 and the normal analysis of dry matter yields followed.

Results and Discussion

Significant differences between the yields of the four grasses were obtained. Their mean yields are shown below.

| Grass | Mean Yield | Significant mean differences |
|---|---|---|
| Danish Italian | 82 | 39 |
| S 22 | 43 | |
| New Danish cocksfoot | 84 | 41 |
| Old Danish cocksfoot | 96 | 53 |

Significant difference = 19 for P = .05

S.E. = $\pm$ 6.6

These results are shown in the attached histogram. Once again S 22 proved less productive in this trial than Danish Italian. This would indicate that under conditions prevailing in this area Danish is the superior Italian ryegrass in early spring. All other recorded work of this sort has indicated that S 22 was better than any other Italian but none of the work has been done in Scotland.

One-year-old cocksfoot has again outyielded the Danish Italian as in 1958 but only by a little. The-two-years-old cocksfoot showed the advantage of its long establishment by its slightly higher yield. That this was not higher may have been due in part to a heavy infection of rust disease that affected both the cocksfoots in September, 1958. From this trial and the 1958 series, cocksfoot seems able to rival

Italian ryegrass as an early yielder. The only puzzle is to know why it yielded so poorly relative to Italian ryegrass in the original species assessment trial in 1957. The only explanation that can be offered is that the original trial was conducted on an area of rather heavy loam while the fertiliser trials were all on a light sandy area. Cocksfoot is traditionally suited to light soil and it could be that this affects its productive ability even in very early spring.

The fertiliser treatments also produced significant results which are shown in the second histogram.

| Fertiliser Treatments nitro-chalk in cwts. per acre | Mean Yield | Mean differences |
|---|---|---|
| 0 | 53 | |
| | | 20 |
| 2 | 73 | |
| | | 38 |
| 4 | 91 | |
| | | 34 |
| 6 | 87 | |

Significant difference = 19 for P = .05

S.E. = $\pm$ 6.6

These results show the interesting feature of a depression of yield at the highest, 6 cwts. level of nitro-chalk. In 1958 the graph of fertiliser response merely showed diminishing returns. The length of time between applying the nitro-chalk and harvesting the resultant growth was twenty days less in 1959 than in 1958. In spite of the difference in growing conditions in the two springs it seems possible that a very high rate of fertiliser given in one application could at first retard growth. Had harvesting taken place even a few days later the same picture of diminishing returns shown in 1958 might have been recorded.

There was no interaction between the four grasses and the different levels of nitro-chalk. It seems fairly conclusive that in the early spring period there is no difference in the efficiency with which one grass utilises available nitrates compared with another. This does not preclude such a difference at other times of the year nor between other grasses not included in these trials. In the early spring period, growth ability and the power of responding to nitrogenous fertilisers seems to depend largely on the grass strain or species employed.

Conclusion

This trial was a very satisfactory one since it verified the 1958 results and showed the worth of cocksfoot. It also served to show that between 2 and 4 cwts. of nitro-chalk represented an optimum spring application for very early spring production.

## AUTUMN FERTILISER TRIAL 1959

### Introduction

The 1958 Autumn Fertiliser trial had produced such a high proportion of winter killing among the ryegrasses that it was necessary to repeat the trial. The aim of the 1959 trial was to ascertain if the results obtained in 1958 were chiefly a result of the abnormal weather conditions in that spring or the result of the autumn treatments. The new trial included cocksfoot and Italian ryegrasses and was so designed that the effects of both autumn and spring nitrogenous fertiliser on spring yield could be measured.

### Materials and Method

After the 1958 trial exactly the same procedure was adopted as in the spring Fertiliser Trial. The cocksfoot drills were retained while the rest was ploughed. A new seeding of Danish cocksfoot replaced H.I. and S 22 and Danish Italian were resown.

In the first week of August, 1958 3 cwts. per acre of nitro-chalk were applied to half of each replicate. These half replicates were further subdivided in the following March and one half of each was given a further 3 cwts. per acre of nitro-chalk. In this way each replicate contained four subplots, - one for each combination of plus and minus autumn and spring nitrogen.

Unchecked autumn growth had been shown to be detrimental to the spring yield of Italian ryegrass especially when combined with autumn nitrogenous fertilising. For this reason the Italian drills were cut in September while the cocksfoot drills were left uncut.

The cutting was done using the Allen autoscythe which was made to leave two inches of stubble. The aim was not to remove the top growth from the Italian but to retain the plant vigour and stimulate basal tillering. Between the time of this cutting and the first week of December when the usual mid-winter defoliation of all the drills was carried out the Italians produced about four inches of fresh green regrowth. By defoliating in early December it was hoped that rather more recovery growth than in the previous year would occur before possible cold weather in January. In that year defoliation had been in the late part of December and the plants had only a little foliage when severe frost set in. It was hoped that the Italian ryegrasses would in this way suffer less winter killing than in 1958. The cold weather of January and February 1959 did suppress growth and both Italians suffered some damage though S 22 seemed to suffer most. The spring application of nitro-chalk was given on March 4th and harvesting took place on April 20th.

Results and Discussion

Significant differences in dry matter yield were obtained for the four grasses

| Grass | Mean Yields |
|---|---|
| 2 years old Danish cocksfoot | 151 |
| 1 year old Danish cocksfoot | 121 |
| S 22 | 10 |
| Danish Italian | 35 |

Significant Difference = 17 for $P = .05$

S.E. = $\pm$ 5.8

Once again the Italian ryegrasses yielded poorly compared with the cocksfoots in this trial. S 22 was very poor and though there was a significantly higher yield from Danish Italian its mean yield was poor also. The established cocksfoot not only out-yielded the one year old cocksfoot but on this occasion there was a significant difference between their yields.

The fertiliser treatments also gave significant differences in yield that show an interesting pattern of responses.

| Fertiliser treatment | | | | Significant | |
|---|---|---|---|---|---|
| Application | Autumn | Spring | Mean Yield | Mean Differences | |
| A | + | + | 103 | | |
| | | | | 32 | |
| B | + | - | 71 | | |
| | | | | 17 | 48 |
| C | - | + | 88 | | |
| | | | | 33 | |
| D | - | - | 55 | | |

Significant difference = 17 for P = .05

S.E. = ± 5.8

The most significant difference occurred between no fertiliser and the double application, with the single spring and autumn applications giving smaller significant differences. Although these were the chief differences to reach significance the others are interesting too. By taking the mean yield of 55 that was obtained without fertiliser as the base figure the increase in yield from spring or autumn fertiliser is seen to be almost a constant irrespective of other additional treatments. Thus by subtracting treatment D from C the difference is 33 while for B from A it is 32. These treatments represent two pairs of autumn treatments both of which show a like increase from spring fertiliser. If the pairs of like spring treatments are now compared (A - C and B - D) the differences are found to be 15 and 16 respectively. From this we can conclude that, while any fertiliser given will produce an increase in spring yield whether it is applied in spring or autumn the same quantity of fertiliser (3 cwts. per acre in this case) gives twice the increase if applied in spring compared to autumn. This may be a freak result but it was obtained from mean yields using four different grasses. One would normally expect diminishing returns from a double application rather than a similar increase in both autumn and spring to single applications. The lower return from the autumn application ignores any increase to the yield that was produced in autumn.

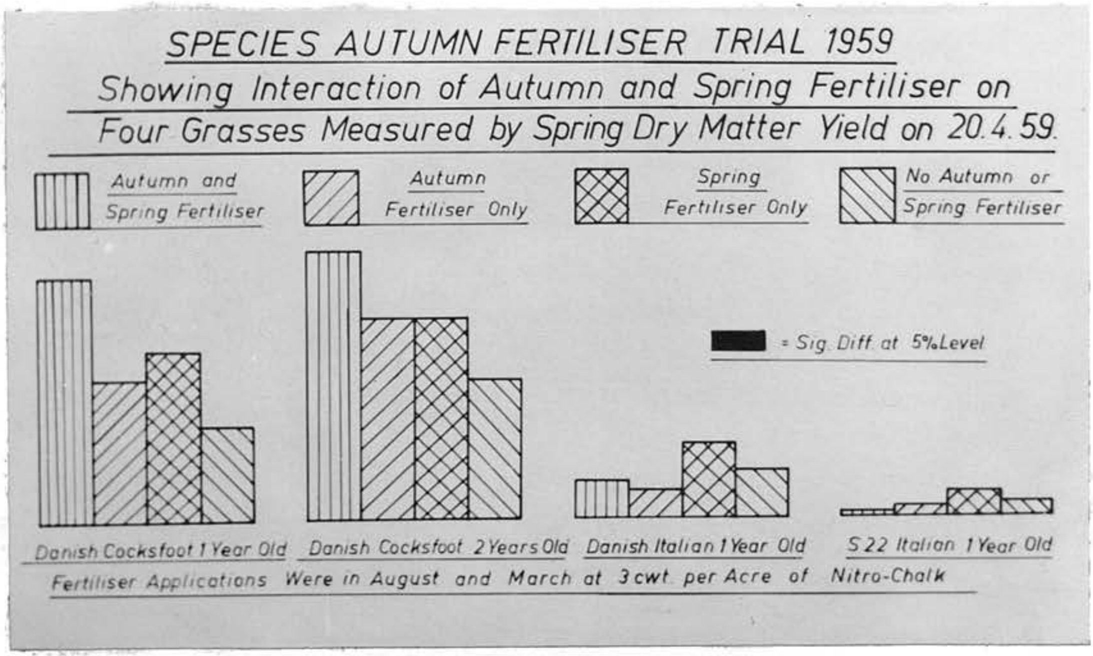
There was a third series of significant differences in this trial in the interactions between the fertiliser treatments and the responses of the four grasses. These are set out in a histogram for convenience but are also shown in tabular form below.

| Grass | Treatments (autumn and spring) | | | |
|---|---|---|---|---|
| | + + | + - | - + | - - |
| Old cocksfoot | 199 | 150 | 150 | 104 |
| New cocksfoot | 182 | 105 | 127 | 71 |
| S 22 | 3 | 7 | 19 | 10 |
| Danish Italian | 28 | 22 | 55 | 35 |

Significant difference = 34 for P = .05

S.E. = $\pm$ 11.7

This illustrates the enormous difference in the total yields of the four grasses as well as the breakdown of these totals. The first


SPECIES AUTUMN FERTILISER TRIAL 1959
Showing Interaction of Autumn and Spring Fertiliser on
Four Grasses Measured by Spring Dry Matter Yield on 20.4.59.
Autumn and Spring Fertiliser
Autumn Fertiliser Only
Spring Fertiliser Only
No Autumn or Spring Fertiliser
= Sig. Diff. at 5% Level
Danish Cocksfoot 1 Year Old
Danish Cocksfoot 2 Years Old
Danish Italian 1 Year Old
S22 Italian 1 Year Old
Fertiliser Applications Were in August and March at 3 cwt. per Acre of Nitro-Chalk

important feature visible in the histograms is the basically different pattern of cocksfoot and Italian yields. Autumn fertiliser clearly benefits the spring yield of cocksfoot while it depresses that of Italian. With Italian the effect of spring after autumn fertiliser is scarcely sufficient to cancel out the reduction produced by the autumn fertiliser. Danish Italian shows this clearly when spring and spring plus autumn fertiliser are compared. S 22 had such a tiny yield that it is hardly possible to draw any conclusions from it. The same trends are shown, however, as with Danish Italian except that the double spring plus autumn application depressed the yield even more than the autumn application alone.

With the Danish cocksfoots the responses were similar except that the two years old cocksfoot gave a bigger response than the one year old. The important difference between them is that the lead which the old cocksfoot possessed in autumn by being strongly established diminished during the winter. The new cocksfoot plants were apparently not in a position to store as much of the benefit from the autumn fertiliser as the established plants. For this reason the greatest difference between their individual yields was for one fertiliser application, in autumn only. On the other hand their smallest individual difference was for the double application in autumn and spring. This treatm ent obviously reduced the differences due to length of establishment to a minimum by stimulating the rate of growth of the young cocksfoot.

It is surprising to find that with the established cocksfoot the mean yield for 3 cwts. of nitro-chalk given in August and March are identical. This must have happened completely by chance. At a cursory glance it might seem that the date of harvesting had come at the precise time when the amount of spring fertiliser taken up was the same as the autumn fertiliser thus giving the same result. This is not so for the yield from the autumn application was produced after December by the autumn residue, if any, plus the stored reserves accumulated earlier in the autumn in the remaining plant tissues. It was this which equalled the utilised spring fertiliser and nothing else. Nevertheless this is of small consequence compared to the other features of the trial.

In conclusion it can be said that the interactions obtained in this trial were among the most interesting obtained. They clearly establish the totally different management techniques necessary to obtain the optimum yield from the grasses employed. Though the density of tillering and growth habit are obvious differences between cocksfoot and ryegrass the amount of food storage which cocksfoot can achieve under soil level compared to Italian ryegrass is different too. This may be possible because cocksfoot can store more reserves in its roots or it may have deeper roots. From observation it seems possibly due to the fact that the actual tiller bases of cocksfoot grow in the soil while Italian ryegrass tillers grow on the soil above the surface.

## AUTUMN RESTING AND FERTILISER TRIAL ON MIXED SWARD 1959

### Introduction

In the 1958 trial negligible differences were recorded between the yields obtained for different degrees of autumn rest. This was presumed to be due to lack of sward vigour in the autumn period and so the trial was repeated in 1959 with the autumn vigour stimulated by nitro-chalk. The purpose was still to study the effect of autumn resting on spring yield.

### Materials and Method

The same trial layout was adopted as in 1958 with three degrees of autumn resting treatment. The rest periods were from mid-August, mid-September and mid-October until December when the usual defoliation took place. As before, the resting periods were preceded by a four-weekly cutting system starting in August which simulated rotational grazing. The alteration in the design of the trial was to substitute two autumn fertiliser treatments for the two harvesting treatments. In this way the application of autumn nitrogen was substituted for early harvesting and the control treatments of no autumn nitrogen for late harvesting.

After the conclusion of the 1958 trial the sward was allowed to grow unchecked until late June when it was cut for hay. This served to exhaust the effects of the spring nitrogen given in March and return the whole area to a uniform sward. Also, the single cut enabled the cocksfoot plants to maintain themselves to best advantage in the sward. It was desired to retain as much cocksfoot as possible since it was the best yielding early grass present in the sward. By July no difference was apparent in the vigour or composition of the subplots. For this reason it was considered justifiable to use the same trial area again in the absence of any other suitable sward.

The substitution of autumn fertiliser treatment for harvesting treatment was done because this caused least change to the layout and because any hidden effects left from the 1958 trial would be least in these plots. It was desired to contrast the effects of the autumn nitrogen treatments and the two harvesting treatments left plots most suited to this. The reason was that only one square yard of each had been cut on the specified harvesting date, which represented approximately 4% of their total area so the differential effects from the two harvesting dates were virtually nil.

The whole trial area was cut at the beginning of the resting period on August 14th and nitro-chalk at 3 cwts. per acre was applied to those subplots due to receive it. Half of these subplots received a second application at the same rate on March 5th together with half the number of subplots which had received no autumn fertiliser. Thus there were four different fertiliser treatments in all, corresponding to the four possible combinations of fertiliser and no fertiliser in spring and autumn. Harvesting of the spring material took place on April 30th using the modified Tarpen hedge-trimmer as in 1958. Each plot had nine cuts of one square foot each bulked together into a single sample and used as the measure of yield. Dry matter estimations were made and the results subjected to statistical analysis.

## Results and Discussion

Significant results were obtained for the autumn resting treatments which are set out below. These show that the long rest period from mid-August gave a significantly higher yield in spring than resting from mid-September or mid-October.

| Resting Treatment | Mean Yield | Mean Difference |
|---|---|---|
| From August to December | 221 | |
| From September to December | 190 | 31 |
| From October to December | 190 | |

Significant difference = 26 for P = .05

S.E. = $\pm$ 8.6

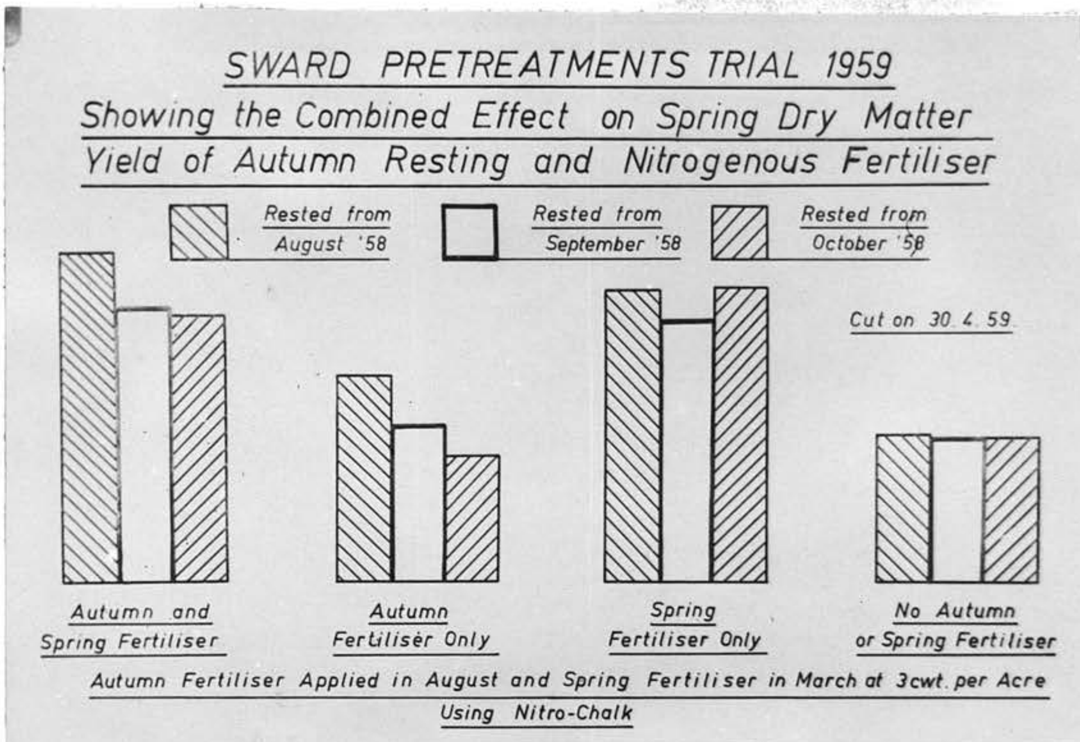
It is interesting to note that no difference occurred between the September and October resting periods indicating that any benefit that can be gained occurs in the early period of August to September. This confirms the previous contention that negligible autumn growth takes place after mid-September.

The nitrogenous fertiliser treatments also produced significant results.

| Fertiliser Treatments | Autumn | Spring | Mean Yields | Differences |
|---|---|---|---|---|
| A | + | + | 262 | |
| | | | | 113 |
| B | + | - | 149 | |
| | | | | 107 |
| C | - | + | 256 | |
| | | | | 123 |
| D | - | - | 133 | |

Significant different = 35 for P = .05

S.E. = $\pm$ 12.0


SWARD PRETREATMENTS TRIAL 1959
Showing the Combined Effect on Spring Dry Matter Yield of Autumn Resting and Nitrogenous Fertiliser
Rested from August '58
Rested from September '58
Rested from October '58
Cut on 30.4.59.
Autumn and Spring Fertiliser
Autumn Fertiliser Only
Spring Fertiliser Only
No Autumn or Spring Fertiliser
Autumn Fertiliser Applied in August and Spring Fertiliser in March at 3cwt. per Acre
Using Nitro-Chalk

The feature of these results which is most striking is that the spring application of fertiliser produced an enormous increase in yield compared to the autumn application as shown by C compared to B. Furthermore, this increase from the spring application is irrespective of the previous autumn treatment as shown by A and C. That this is due to there being no carry-over of benefit from autumn fertiliser is confirmed by comparing the yields from B and D treatments. It is remarkable how small the differences are in these comparisons. Altogether this shows very clearly that the best management policy for spring production with regard to fertiliser is to withhold nitrogen until spring. This is illustrated clearly in the attached histograms which show the interaction of fertiliser and resting treatments. There were no statistically significant trends in this but it serves the useful purpose of showing how the effects of these two factors built up the total results.

When autumn fertiliser was given, the longest rest period combined with it to give the highest yields. Without autumn fertiliser almost no differences occurred which confirmed that the previous year's impression on this point had been correct. It was this suspicion that stimulated vigour was necessary to produce any response to resting that had led to this trial being done in 1959.

The large benefit that a spring application of fertiliser gives is clearly visible. With only a spring application there is no difference between the yield from the longest and the shortest rest period though there is a slight decrease between these two extremes. It is illuminating to see that the most indulgent treatment of a long rest period from August with nitro-chalk in both autumn and spring produced little more than no rest until October with a spring application of fertiliser.

Conclusion

This trial, by its results, confirms the suspicions aroused by previous trials that many of the views expressed on the value of autumn management are difficult to substantiate in practical experiments.

## LAYOUT

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REP. I | 4 Oct. | 6 Oct. | 4 Aug. | 2 Aug. | 2 Sept. | 4 Sept. | 2 Oct. | 0 Aug. | 6 Aug. | 0 Sept. | 6 Sept. | 0 Oct. |
| REP. II | | | | | | | | | | | | |

FIGS. REPRESENT N/C. IN CWTS. / ACRE.
MONTH REPRESENTS DATE RESTING BEGAN.

## AUTUMN RESTING AND FERTILISER TRIAL ON DANISH ITALIAN SWARD 1959

### Introduction

The 1958 trial on Italian sward had given useful results showing the effect of autumn rest on this type of sward. It was desired to extend this investigation to cover the effect of autumn rest when combined with the autumn application of nitrogenous fertiliser at varying rates. This was done in 1959 in a new trial designed in such a way that four levels of fertiliser were used in conjunction with three autumn resting treatments. This type of trial gives an accurate measure of any carry-over potential from autumn fertiliser treatment until spring.

### Materials and Method

The new trial was sown on May 20th 1958 at Boghall farm using Danish Italian ryegrass. The various combinations of autumn resting and fertiliser treatments were allocated at random to the twelve subplots in each replicate. There were four replicates. Establishment was rapid and even.

In early August, on the 9th, the resting treatments began and the autumn fertiliser was applied. The fertiliser used was nitro-chalk and the rates of application were nil, 2, 4 and 6 cwts. per acre. There were three resting treatments extending from early August, September or October until December. Before resting began the plots were subjected to defoliation by cutting once a month from August onwards. The subplots measured two yards by eight which gave a harvesting area of seven square yards after allowing for discards.

Rapid growth followed the application of nitro-chalk and its effects were still visible as a deeper green colour after the December defoliation in the subplots that had received 6 cwts. per acre. No Spring fertiliser was given and harvesting took place on April 3rd. Cutting was done with the Allen autoscythe and the total yield harvested from the seven square yards was collected and weighed in the laboratory. The usual dry matter estimations provided the basis for the statistical analysis.

Results and Discussion

The analysis showed that a gradation of fertility existed which rose from replicate four to replicate one but this did not appear to upset the other results.

| Fertiliser treatments cwts. of nitro-chalk per acre | Mean Yields | Mean Differences |
|---|---|---|
| 0 | 156 | |
| | | 51 |
| 2 | 205 | |
| 4 | 191 | |
| 6 | 186 | |

Significant difference = 52 for P = .05

S.E. = $\pm$ 18.1

In this analysis the fertiliser treatments did show a significant difference at the 5% level in the "F" test but just failed to reach significance in the "t" test.

The resting treatments gave a more precise series of results.

| Resting treatment | Mean Yield | Mean Difference |
|---|---|---|
| Resting from August to December | 227 | |
| Resting from September to December | 184 | 77 |
| Resting from October to December | 150 | |

Significant difference = 52 for P = .05

S.E. = $\pm$ 18.1

These figures show that resting did have a positive benefit if it was begun by early August. Later than that autumn growth had presumably slowed down or stopped and so no further food reserves were accumulated and hence no benefit occurred to the spring yield.

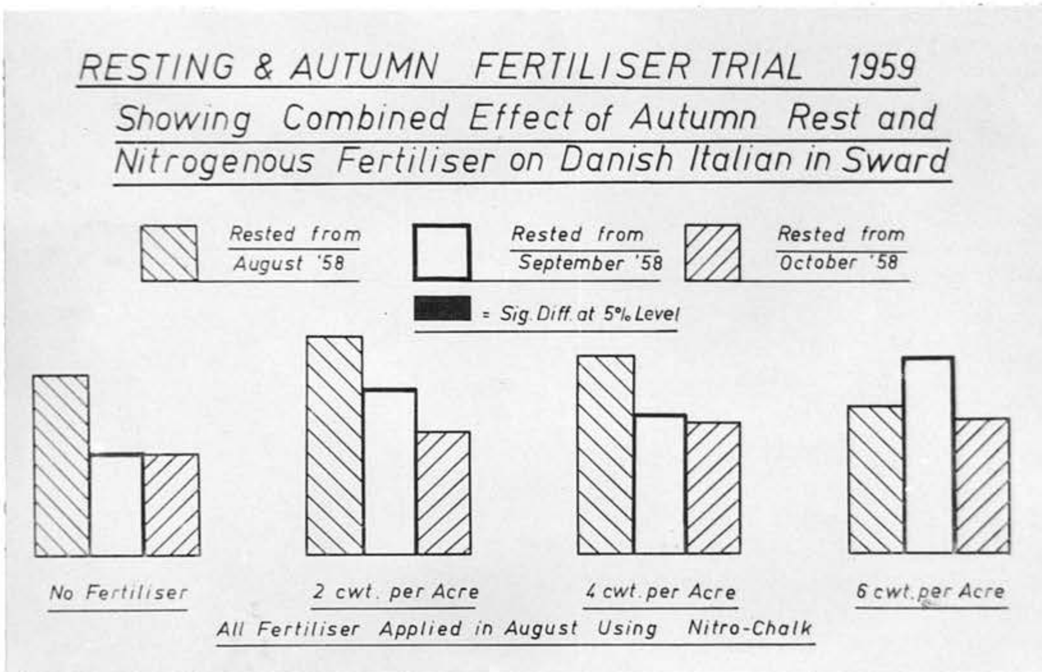
The interaction of resting and fertiliser treatments also provided significant results.

| Resting from - | August | Mean Yields September | October |
|---|---|---|---|
| Fertiliser | | | |
| 0 | 219 | 126 | 125 |
| 2 | 266 | 202 | 148 |
| 4 | 242 | 169 | 163 |
| 6 | 181 | 239 | 164 |

Significant difference = 52 for P = .05

S.E. = $\pm$ 18.1

These results are shown by the attached histograms. When no nitrogenous fertiliser was given the long August to December rest was significantly more advantageous to spring yield than resting from September or October until December. The same was true of resting from August onwards when 2 and 4 cwts. per acre of nitro-chalk were given. With 6 cwts. per acre, however, a significantly greater spring yield resulted from September


RESTING & AUTUMN FERTILISER TRIAL 1959
Showing Combined Effect of Autumn Rest and Nitrogenous Fertiliser on Danish Italian in Sward
Rested from August '58
Rested from September '58
Rested from October '58
= Sig. Diff. at 5% Level
No Fertiliser
2 cwt. per Acre
4 cwt. per Acre
6 cwt. per Acre
All Fertiliser Applied in August Using Nitro-Chalk

to December resting than when associated with either a longer or a shorter autumn rest period. The combination of long rest, from August, and a high rate of fertiliser, at 6 cwts. per acre, decidedly depressed the spring yield compared with either the same rest period and less fertiliser or the same fertiliser and a shorter rest.

The results for the October fertiliser treatments were all very similar to each other due presumably to the inactivity of plant growth by that time. Autumn management techniques such as resting and fertilising apparently must be carried out during August or at latest by early September to produce an effective result measureable in the spring yield.

The results of this trial coincide with those obtained from the autumn pre-treatments trial on mixed sward already recorded. Autumn resting plus 3 cwts. per acre of fertiliser in that trial gave the same general trend as in this one. However, the results of this trial are in direct conflict with those obtained in other trials with Italian ryegrass. In the 1958 trial on Italian in sward a direct depression of spring yield resulted from autumn resting which was proportional in severity to its duration. In other trials Italian ryegrass has generally shown a negative response to autumn rest. The statistical layout and autumn management was not the same in this trial as in the 1958 Italian sward trial but this does not explain the different pattern of results. In fact there seems no clear explanation for the differences. It can be surmised that the period of severe weather in April 1958 was a more rigorous test of hardiness for Italian ryegrass than anything that occurred in 1959. This could explain the difference in the two seasons' results in the Italian sward trials.

Treated in isolation it could be concluded from this trial that the spring yield of Italian ryegrass benefits from autumn resting but when other trials are considered this must be modified. Thus the broad conclusion is that under sward conditions, Italian ryegrass has been found to give variable reactions to autumn resting treatments. To clarify the causes of this would require further investigation. The results of this trial give weight to the point made earlier that while some problems have been answered in these investigations others still require further study.

## CONCLUSION

As the information which has been gained has been set out trial by trial it is in a piecemeal state. By way of conclusion it is desirable to gather these individual findings together and show them in relation to the work as a whole. For this purpose it is the most salient features rather than the minor ones which need co-ordinating.

In point of time the first major result was to discover that the Italian ryegrasses were supremely suited to early spring production. Not only did their spring production outyield all other grasses on trial but they established strongly in far quicker time from the date of seeding. On the other hand grasses such as fescues and meadow foxtail were comparatively poor yielders in their first spring. This picture was elaborated in the second spring when the weather conditions showed cocksfoot to advantage. In the growth rate trial the rate of increase of dry matter yield shown by Danish cocksfoot placed it in the position of being the grass with the fastest growth potential of those tested. The Italian ryegrasses were not growing under optimum conditions in this trial so that they could not challenge cocksfoot on equal terms. In another trial on the effects of spring fertiliser which involved both Danish cocksfoot and Danish Italian the Italian appeared to grow faster because, having been at a disadvantage when growth began it had almost caught up with the cocksfoot three weeks later.

An unexpected result in this growth rate trial was that S 215 meadow fescue was the fastest producer of dry matter after cocksfoot. That this was not a purely chance result was shown by its good yield in the third spring. In that year its output was not so outstandingly high as in 1958 but it was still better than the perennial ryegrasses. It would seem that the weather conditions in 1958, when a rapid change took place from cold to warm conditions, favoured meadow fescue. In consequence it was able to show a large and rapid response.

Not only did cocksfoot and meadow fescue make the most rapid first growth in 1958 but cocksfoot and the fescues in general showed the highest recovery rate by yielding the most in a second cut taken within four weeks of the start of spring growth. The same picture presented itself when cocksfoots, timothies and fescues were cut in December, January and February,for cocksfoot in all cases outyielded the others by late March. In 1959, by the third spring, Danish cocksfoot had confirmed its ability to give high spring yields. As a result, though three year old S 170 tall fescue also gave a good output, Danish cocksfoot could be classed as the one perennial grass tested, with the highest potential for early spring production.

Among the Italian type ryegrasses,strain was found to be very important. H.I., though good was not as good as some of the Italians for early spring purposes. Also, it was not particularly winter-hardy. Of the strains in commercial use Danish was found to be more reliable than most. It did not suffer winter killing to the extent that S 22 did and though they occasionally gave comparable spring yields Danish was better able to maintain the high output expected of Italians in adverse circumstances. It could be that other strains of Italian not yet released by the plant breeders for general use will rival Danish Italian. None of these new strains actually outyielded Danish under trial but only a comparatively few strains were available for this testing. As Danish Italian is a commercial or non-pedigree type of grass it is perhaps difficult to use it as a permanent yardstick by which to judge other strains and species. Continental plant-breeders are known to be improving and altering their commercial grasses and it could easily happen that the Danish Italian used in these trials might be replaced by some different type possessing other qualities within a very short time.

Of major concern was the study of the effect upon spring yield of prior resting treatments. Many authorities have held autumn and winter rest to be vitally important. These views were found difficult to substantiate experimentally. The first trial conducted on this topic involved winter resting and it showed that long resting had a slight benefit on spring yield. In the next year autumn resting was tried with no particular trend evident in the results. When a pure Italian ryegrass sward was used a negative response resulted. This tendency was confirmed by a drilled trial which showed that Italian ryegrass yields were depressed by resting, particularly if the rest involved exemption from defoliation in autumn. At the same time this trial showed that cocksfoot did not respond in the same way as ryegrass.

At an early stage it was apparent that nitrogenous fertiliser applied in spring gave a large increase in yield. It was quickly shown that while both crude protein and total dry matter yields were affected by nitrogenous fertiliser it was of more importance to assess the worth of treatments on a dry matter than a protein basis.

In the second and third springs it was established and confirmed that among the highest yielding grasses no differential response potential existed to a given level of nitrogen fertility. That they all grew equally fast in terms of dry matter production was due to the short period in which active spring growth was permitted before harvesting of the material. In this way Danish cocksfoot made as good use of any given rate of nitro-chalk as Italian ryegrass and in a drilled trial roughly equal yields were obtained from each. The optimum rate of fertiliser when nitro-chalk was used was confirmed to be an application of between 2 and 4 cwts. per acre for early spring production.

When autumn fertilising with nitro-chalk was employed a more complex picture was presented because this was combined in most cases with some degree of autumn resting. When the grass concerned was Italian the effects of autumn nitrogen were highly detrimental to spring yield. This effect was modified slightly by frequent autumn defoliation. In this respect cocksfoot again disclosed its totally different character by exhibiting a beneficial response. In this way cocksfoot seems to have a much better storage system for reserves built up in one season for use in the following spring. It could be that the storage ability of Italian is very good but not compatible with its greatest degree of winter hardiness. This would explain how it showed a slight benefit from both autumn rest and autumn fertiliser when grown in sward in 1959. This was a comparable trend to that of the mixed sward containing cocksfoot in the same spring, yet the opposite to its own response in the more severe conditions of the previous spring.

It was shown that autumn applications of nitrogen increased spring production potential but not to the same degree as the same amount of nitrogen applied in spring. With cocksfoot the combined effect of long autumn rest and fertiliser was approximately equal to the effect of spring fertiliser alone. When all three treatments were applied the yield reached a maximum but the extra yield gained was small.

With swards of mixed composition it seems certain that prior resting is beneficial to spring yield but to be effective it must commence in early August in this area. In midwinter rest from defoliation conserves a sward's reserves rather than increases them further. The removal of autumn growth by a single defoliation after growth had ceased showed no adverse effect on spring yield, however.

In the light of these results it can be said that the importance of autumn resting in relation to early spring production, though valuable under certain conditions, seems to have been overstressed in the past.

The benefit to production from the employment of the most suitable species and most suitable strain of that species is very important to the extent that its potential limits the benefit from all other factors.

In many cases the effects of nitrogenous fertiliser, especially if applied in spring, were of much greater magnitude than those produced by other factors. Though its power to stimulate earlier production is limited by climate it is still of great benefit. It is used to best advantage when applied to grasses of the highest yielding potential that are in the most responsive condition. Thus it is the combination of the various factors which gives the maximum results rather than the employment of any one of them alone.

Many of the results obtained in these trials could be obtained under farm conditions but success would depend on a high level of grassland husbandry. This is so, because management controls the constituents present in a sward, their vigour and productivity, the type and quantity of fertilisers applied, the degree of inter-species competition, and the extent and frequency of defoliation. On the careful control of these and other factors depends the date in spring when the first herbage is available for use. Though the demands this makes on management skill are high so too are the possible rewards. This was shown by observing the output of farm pastures in the same area and comparing their earliness with that of the trial plots. The farms concerned used spring applications of nitrogenous fertiliser to encourage earliness but depending on the season, they took from one to two and a half weeks longer to reach the same growth stage. Expressed in another way this means that when the farm pastures had 2-3 inches of grass, which was enough to start grazing, the best of the trial material was already 10-12 inches high and correspondingly thick.

When this study was commenced it was hoped that it might provide some information that would benefit British agriculture. From this point of view, though some of the results obtained were unexpected the investigation has been successful and rewarding.

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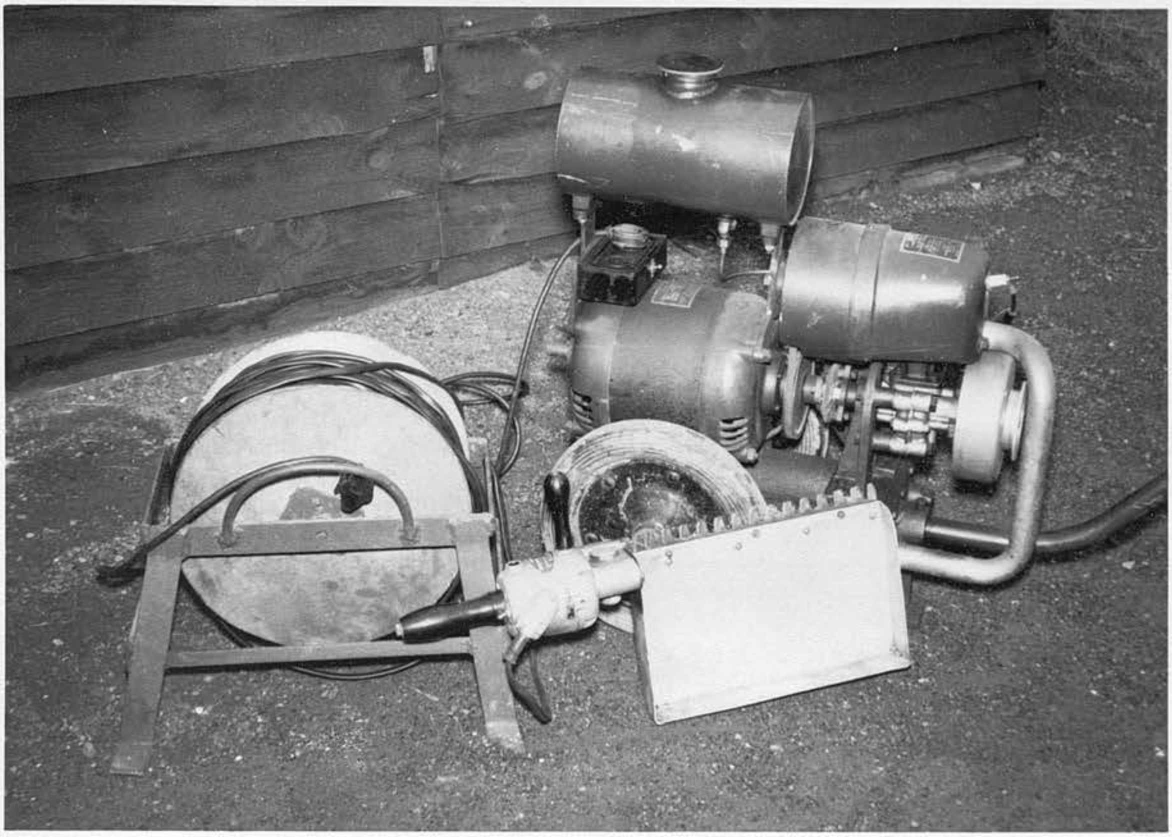
This photograph shows the Allen autoscythe
with its close-set cutter-bar as used on
sward trials.



This photograph shows the modified Tarpen hedge-cutter with collecting pan used to harvest short herbage from sward trials. Power is supplied from the portable generator shown behind and the winding drum carries flex.

Species and Strains Potentiality Trial 1957

Photographs of the Grasses taken in the first week of April, 1957

I II III IV

I. Danish cocksfoot

II. S 215 meadow fescue

III. Danish Italian ryegrass

IV. H.I. ryegrass

V VI VII VIII

V. New Zealand perennial ryegrass

VI. McGill & Smith's "Early Fescue"

VII. S. 22 Italian ryegrass

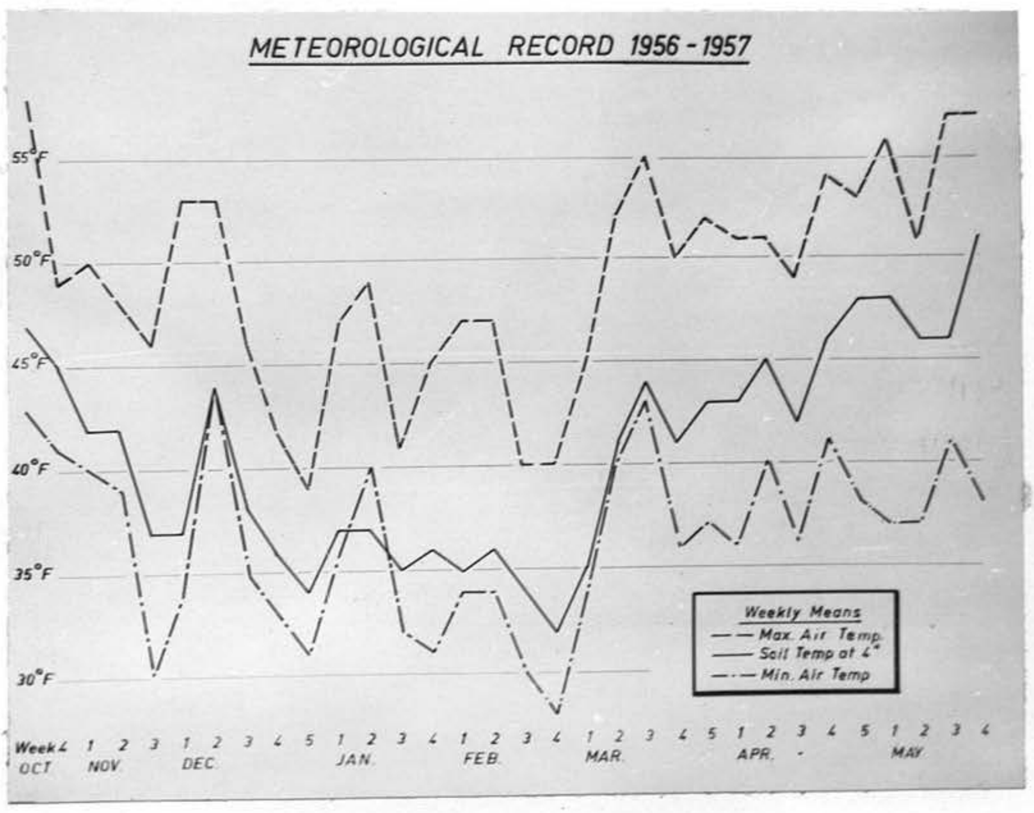
VIII. Meadow foxtail

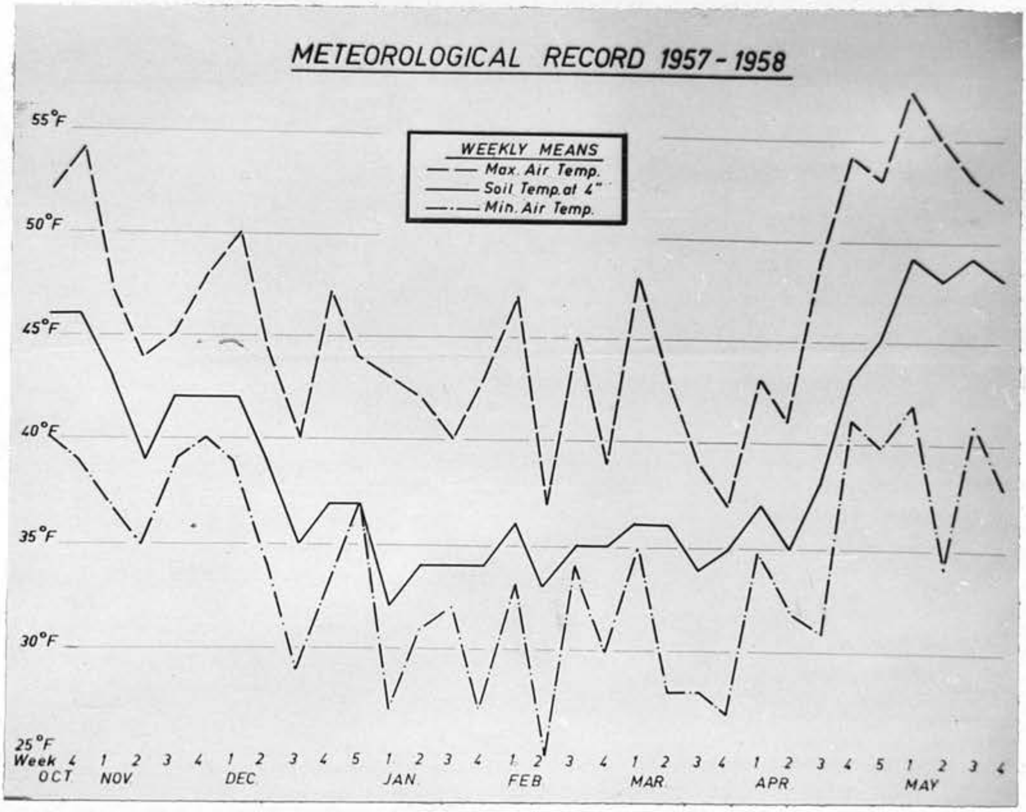

IX. S 170 tall fescue X. S 24 perennial ryegrass

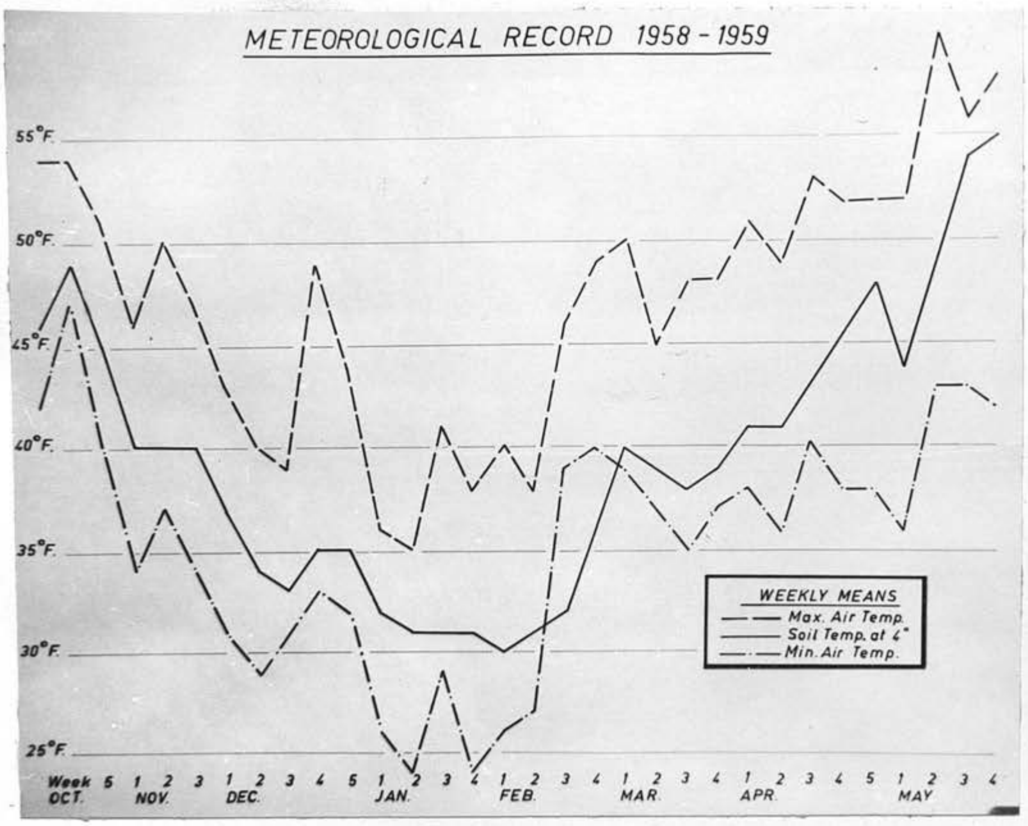
XI. Ayrshire perennial ryegrass XII. Rhenish tall fescue


Close view of meadow foxtail showing the comparison between it and S.22 on the left and S 170 on the right.

The same trial in December after the drills had been defoliated.




METEOROLOGICAL RECORD 1957 - 1958
WEEKLY MEANS
Max. Air Temp.
Soil Temp. at 4"
Min. Air Temp.
55°F
50°F
45°F
40°F
35°F
30°F
25°F
Week 4 1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 5 1 2 3 4
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY


METEOROLOGICAL RECORD 1958 - 1959
WEEKLY MEANS
Max. Air Temp.
Soil Temp. at 4"
Min. Air Temp.
55°F.
50°F.
45°F.
40°F.
35°F.
30°F.
25°F.
Week 5 1 2 3 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 5 1 2 3 4
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY